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Office of Environmental Management – Grand Junction

MOAB UTAH UMTRA

UMTRA Project

Alternatives Analysis for Long-Term Ground Water Remediation Moab Site, Located Near Moab, Utah

March 2006

U.S. Department of Energy

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Work Performed Under DOE Contract No. DE–AC01–02GJ79491
for the U.S. Department of Energy Office of Environmental Management.

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Work Performed by S.M. Stoller Corporation under DOE Contract No. DE–AC01–02GJ79491
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Grand Junction, Colorado

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Acronyms

bgs	below ground surface
CFR	*Code of Federal Regulations*
cfs	cubic feet per second
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ft	feet/foot
FTE	Full Time Equivalent
gpm	gallons per minute
hp	horsepower
mg/L	milligrams per liter
NRC	U.S. Nuclear Regulatory Commission
O&M	Operations and Maintenance
ppm	parts per million
SOWP	Site Observational Work Plan
TDS	Total Dissolved Solids
UIC	underground injection control
UMTRA	Uranium Mill Tailings Remedial Action [Project]
UMTRCA	Uranium Mill Tailings Radiation Control Act
UPDES	Utah Pollutant Discharge Elimination System
U.S.C.	*United States Code*
USF&WS	U.S. Fish and Wildlife Service
VE	Value Engineering

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Summary

This alternatives analysis report addresses the need to remediate ammonia-contaminated ground water present beneath and in the vicinity of the uranium mill tailings pile located at the Moab, Utah, Project Site. The Moab site is managed by the U.S. Department of Energy (DOE) in Grand Junction, Colorado, and is undergoing remediation in accordance with Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA) (Title 42 *United States Code* [U.S.C.] Part 7901 et seq.).

In September 2005, DOE published the *Record of Decision for the Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah* (70 FR 2005). The purpose of the record of decision was to announce DOE's plan to implement the preferred alternative identified in the *Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah, Final Environmental Impact Statement* (DOE 2005a) (final EIS). Implementation of the preferred alternative in the final EIS will result in the mill tailings and other contaminated material from the Moab milling site being removed and shipped to a site near Crescent Junction, Utah, for long-term management.

An evaporation pond located on the top of the present mill tailings pile at the Moab site is currently used for ground water treatment. This pond is used to treat ammonia-contaminated ground water present in the upper aquifer downgradient of the tailings pile. The concentration of ammonia in the ground water averages 900 milligrams per liter (mg/L) and has been detected as high as 1,700 mg/L. Treatment of the ground water is necessary to prevent elevated concentrations of ammonia in the aquifer from migrating to the ecosensitive backwaters in the nearby Colorado River. The concentrations of ammonia are at levels that may have detrimental effects on aquatic life in the near-shore portions of the river. Of particular concern is the presence of two fish species protected under the Endangered Species Act (16 U.S.C. 1973), the razorback sucker and the Colorado pikeminnow.

A previous screening process identified five contaminants of potential concern in ground water at the Moab site with concentrations above appropriate standards or benchmarks for protection of aquatic organisms in surface water: ammonia, copper, manganese, sulfate, and uranium. Consequently, the compliance strategy for the remediation of the Moab site ground water focuses on being protective of the ecological receptors (i.e., endangered fish) and achieving compliance goals (i.e., surface water standards) in the river. Ammonia is the key constituent driving the ground water remedial action because of its high concentrations in the tailings seepage and ground water and its toxicity to aquatic organisms.

During milling operations, the tailings pond contained fluids with total dissolved solids (TDS) concentrations ranging from 50,000 to 150,000 mg/L. Because of these salinities, they had sufficient density to migrate vertically downward through the freshwater system and into a layer of brine under the Moab site. This downward migration of the tailings pond fluids into the saltwater system is believed to have created a reservoir of ammonia that now resides below the brine surface. Under present conditions, the ammonia plume beneath the brine surface represents a potential long-term source of ammonia to the less-saline ground water above the brine.

Contaminated ground water is currently being managed at the Moab site by pumping the ground water from a number of extraction wells established in three configurations, to the evaporation pond located on the top of the tailings pile. The extraction wells are located adjacent to the Colorado River. The contaminated ground water from the extraction wells is pumped through a common pipeline to the evaporation pond. A sprinkler system is used on the tailings pile to enhance evaporation of the contaminated water. With implementation of the preferred alternative in the final EIS, the mill tailings and other contaminated material from the Moab milling site will be removed and shipped to the Crescent Junction site for management, and the existing evaporation pond will be removed.

The Configuration 1 wells were installed approximately 100 feet (ft) from a steep bank that forms the west bank of the Colorado River during relatively high runoff periods. These wells intercept ground water that was contaminated by seepage from fluids in the Moab tailings pile. Spacing between the wells is about 25 ft. There are a total of 10 Configuration 1 extraction wells (well numbers 470–479) and 25 observation wells and piezometers for monitoring aquifer responses to pumping and other hydraulic stresses. The extraction wells are 4 inches in diameter and are installed to depths of about 21–25 ft below ground surface (bgs). Eight of the 10 wells are screened over identical intervals of 10.3 to 19.7 ft bgs, and the remaining two are screened over depths of about 9 to 24 ft bgs. The depths and screened intervals of the Configuration 1 observation wells vary so that information collected from them can be used to portray three-dimensional responses of the alluvial aquifer and the Colorado River to ground water pumping.

The Configuration 2 wells, used for both extraction and injection, are located north of the Configuration 1 site and approximately 50 ft from the river. The intent in placing these wells closer to the river is to minimize the time for injected uncontaminated water to reach backwater areas of the Colorado River near its west bank. Injection of uncontaminated water (from the river) is conducted to provide a hydrological barrier to prevent contaminated ground water from reaching the near-shore portion of the river. The spacing between the Configuration 2 extraction/injection wells is approximately 30 ft.

There are a total of 10 Configuration 2 extraction/injection wells (well numbers 570–579), all of which have a casing diameter of 6 inches. Five of the Configuration 2 wells are considered shallow and are installed to a depth of 31.3 ft. The other five wells are classified as deep wells and extend to 41.3 ft. All shallow extraction wells are screened between depths of 15 and 30 ft bgs, which places them noticeably deeper than Configuration 1 extraction wells (mostly screened between 10 and 20 ft bgs). The deep well screens span depths of 25 to 40 ft bgs. The shallow and deep wells alternate with one another along the well field; even-numbered wells are shallow, and odd-numbered wells are deep. A total of 19 observation wells and floodplain piezometers are used to monitor alluvial aquifer and Colorado River responses to injection or extraction in Configuration 2. All but three of the observation wells are classified as shallow; the screened intervals of most shallow monitor wells are located between 10 and 20 ft bgs.

The deep wells were added to Configuration 2 for the purpose of ensuring that river water injected into extraction wells would spread laterally toward the river over a wide vertical interval. It was believed that injection of uncontaminated water in both shallow and deep wells would cause a larger portion of backwaters in the river to undergo more dilution of ammonia than would occur using shallow wells only. Greater mass removal of ammonia contamination during pumping was also surmised as being a possible benefit of using deep wells.

The Configuration 3 wells are located approximately 75 to 100 ft from the river and are also intended for either extraction or injection. These wells are numbered 670–679. The 10 Configuration 3 wells are all completed at a depth of 45 ft bgs, and the well screens span depths between 15 and 45 ft bgs. There are approximately 12 observation wells and piezometers in the vicinity of Configuration 3 for monitoring alluvial aquifer and Colorado River responses to pumping or injection.

Previously, DOE has screened potential treatment technologies that would be applicable for treatment of ammonia and other contaminants of concern. These are described in detail in Section 9.0 of the *Site Observational Work Plan for the Moab, Utah, Site* (DOE 2003b). This screening analysis concluded the following:

1. The level of treatment will depend largely on the selected method of effluent discharge. Four preliminary discharge options were considered for the Moab site:
   - Discharge to surface water
   - Evaporation
   - Deep well injection
   - Shallow well injection
2. The treatment goals for the selected remedy will consider the discharge option, risk analysis, and regulatory requirements. The following treatment options were considered during the screening process:
   - Standard evaporation
   - Enhanced evaporation
   - Distillation
   - Ammonia stripping
   - Ammonia recovery
   - Chemical oxidation
   - Zero-valent iron
   - Ion exchange
   - Membrane separation
   - Sulfate coagulation

These treatment alternatives were considered based on the ability to treat both ammonia and TDS as the primary constituents of concern. Based on further evaluation, it has been determined that ammonia is the only constituent of concern that will be treated to meet appropriate standards. In this study, an alternative typically consists of three subsystems: ground water extraction, treatment, and disposal. Each of these subsystems is described and evaluated, and alternatives composed of various combinations of the subsystems are subsequently identified and discussed.

This study produced the following alternatives that were evaluated in detail.

1. Extraction of 150 gallons per minute (gpm) of ground water from wells, followed by well injection into or below the Paradox Formation.
2. Extraction of 150 gpm of ground water from wells, followed by treatment in an evaporation pond system.
3. Extraction of 150 gpm of ground water from wells, followed by treatment using ammonia stripping and ion exchange, and disposal via well injection into or below the Paradox Formation.
4. Extraction of 150 gpm of ground water from wells, followed by treatment using ammonia stripping and ion exchange, and disposal via shallow well injection into the alluvial aquifer.
5. Extraction of 150 gpm of ground water from wells, followed by treatment using ammonia stripping and ion exchange, and disposal via an infiltration gallery.
6. Extraction of 150 gpm of ground water from wells, followed by treatment using ammonia stripping and nitrification, and disposal via well injection into or below the Paradox Formation.
7. Extraction of 150 gpm of ground water from wells, followed by treatment using ammonia stripping and nitrification, and disposal via well injection into the alluvial aquifer.
8. Extraction of 150 gpm of ground water from wells, followed by treatment using ammonia stripping and nitrification, and disposal in an infiltration gallery.

9A. Diversion of 150 gpm of Colorado River water, followed by well injection into the alluvial aquifer.

9B. Diversion of 150 gpm of Colorado River water, followed by infiltration gallery injection into the alluvial aquifer.

10. Extraction of 150 gpm of ground water from wells for blending with 750 gpm of Colorado River water, followed by nitrification treatment and shallow well injection into the alluvial aquifer.
11. Extraction of 150 gpm of ground water from wells for blending with 750 gpm of Colorado River water, followed by nitrification treatment and disposal in an infiltration gallery.

12A. Diversion of 2 cubic feet per second (cfs) of Colorado River water, followed by wetlands percolation into the alluvial aquifer.

12B. Diversion of 2 cfs of Colorado River water, followed by spreading basin percolation into the alluvial aquifer.

The following aspects of each of the alternatives are described and discussed:

- System components and the spatial requirements
- The alternative's ability to achieve ground water and Colorado River remediation objectives
- Capital cost of the alternative
- Operations and maintenance (O&M) costs
- Safety considerations
- Implementation factors and limitations

The development and evaluation process steps included development of a conceptual design for each component of an alternative. The conceptual design sized each component on the basis of desired flow rate, expected ground water and/or Colorado River water quality, and the goal of producing a treated effluent with an ammonia concentration of 3 mg/L or less. The capital cost of each alternative was based on its conceptual design and the assumption that standard construction methods will be used to construct the alternative. The capital costs were derived using estimated quantities to construct system components, and unit prices of the components were obtained from handbooks (e.g., Means 2004) and vendor quotes.

Each capital cost estimate allowed for contingency. Based upon DOE Project Management Practices (DOE 2000), 30 percent contingency was added to each estimate. The O&M cost for each alternative included labor, energy, and/or chemical costs. Chemical costs were based on vendor quotes. Safety considerations included the safety level required for construction and the associated effects on labor productivity (Means 2004). A qualitative estimate of the safety risk to O&M workers was included in each alternative. Using assumptions in the conceptual design, any process development steps such as pilot plants or computer modeling were identified, along with descriptions of potential limitations to the alternatives.

The various treatment alternatives were compared to each other using a ranking process in which lower scores signified preferred alternatives. The alternative with the lowest score would be to inject 150 gpm of Colorado River water directly into the shallow freshwater aquifer. This alternative would inject water that has less than 3 mg/L of ammonia while having the lowest capital and O&M costs. Further, this alternative poses a low safety risk to workers.

To further assess the above-mentioned alternative, additional ground water modeling and testing should be done to predict ground water and near-shore surface concentrations in the Colorado River due to injection of Colorado River water. The modeling should also address whether the freshwater mound produced by the injection decreases the natural ground water flow gradient beneath the tailings pile, thus increasing the projected cleanup time for ammonia beyond 75 years. These uncertainties require modeling to estimate ammonia concentration in the Colorado River at near-shore locations, and this alternative does not address the concentration of ammonia that is presently in the ground water near the existing extraction wells.

A Value Engineering (VE) assessment was conducted on the draft Alternatives Analysis report. The objectives and outcomes for the VE analysis are:

- Use VE as a valuable tool to generate a range of solutions to engineering problems and to evaluate the best solution to satisfy project needs.
- Select an alternative for the problem that meets the regulations and that will gain acceptance by the U.S. Nuclear Regulatory Commission, the State of Utah, and others.
- Determine a phased concept of treatment that addresses the strict cleanup objectives, considers the life of the project, and addresses potential changes in land use.
- Select an alternative that meets the objectives of the Biological Opinion from the U.S. Fish and Wildlife Service (USF&WS)—within 10 years to be protective for the endangered fish in the Colorado River.

The problem was defined as the following:

Ammonia concentrations in the surface water expressions in the low-water and backwater areas next to the Colorado River render these areas not protective of endangered fish. DOE is obligated by the Biological Opinion from the USF&WS to establish conditions that are protective within 10 years. DOE must have some active strategy to fulfill this obligation. Further, the potential exists to avoid extended, long-term ground water remediation (about 75 years) of the aquifer (this aquifer is not a drinking water source and may qualify for supplemental standards due to limited yield).

The recommendations from the VE assessment are:

- Divert up to 150 gpm from the Colorado River, pass it through in-line filtration, and inject the filtered water into a well field located adjacent to the river. The injection area near the river would provide dilution to the backwater channels with the potential for endangered fish habitat.
- Divert an additional 900 gpm from the Colorado River and route it through a surface water infiltration system located between the river and the tailings pile.
- Place an extraction well field between the toe of the pile and the surface water infiltration system proposed above to intercept contaminated ground water under and immediately downgradient of the pile and place this water in a lined, evaporation pond. The evaporation pond could use enhanced evaporation methods (e.g., TurboMist) that could significantly reduce the pond size.

Based upon the VE assessment recommendations, additional modeling, engineering data, and equipment demonstration needs were identified.

1.0 Introduction

This alternatives analysis addresses the need to remediate ammonia-contaminated ground water present beneath and in the vicinity of the uranium mill tailings pile located at the Moab Uranium Mill Tailings Remedial Action (UMTRA) Project Site. The Moab UMTRA site is managed by the U.S. Department of Energy (DOE) Office of Environmental Management in Grand Junction, Colorado, and is undergoing remediation in accordance with Title I of the Uranium Mill Tailings Radiation Control Act (UMTRCA) (42 U.S.C. 1978). This site is a former uranium-ore processing facility located about 3 miles northwest of the city of Moab in Grand County, Utah, and lies on the west bank of the Colorado River at the confluence with Moab Wash (Figure 1-1).

1.1 Background

In September 2005, DOE published the *Record of Decision for the Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah* (70 FR 2005). The purpose of the record of decision was to announce DOE's plan to implement the preferred alternative identified in the *Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah, Final Environmental Impact Statement* (DOE 2005a) (final EIS). Implementation of the preferred alternative in the final EIS will result in the mill tailings and other contaminated material from the Moab milling site being removed and shipped to a site near Crescent Junction, Utah, for management in a disposal cell.

Currently, there is an active evaporation pond located on the top of the present mill tailings pile at the Moab site. This pond is used to treat ammonia-contaminated ground water present in the shallow aquifer downgradient of the tailings pile. The concentration of ammonia in the shallow ground water averages 900 milligrams per liter (mg/L) and has been detected at levels as high as 1,700 mg/L. At a minimum, management of ground water is necessary to prevent elevated concentrations of ammonia present in the aquifer from migrating to the near-shore portions of the adjacent Colorado River. This management of ground water may include treatment to decrease ammonia concentrations. The dissolved ammonia may have detrimental effects on aquatic life in the near-shore portions of the river where most of the site's ground water would enter the surface water. Of particular concern is the presence of two fish species that are protected under the Endangered Species Act (16 U.S.C. 1531–1544): the razorback sucker and the Colorado pikeminnow.

1.2 Hydrological Conditions

The uppermost aquifer at the Moab site occurs in unconsolidated Quaternary alluvial material deposited on older bedrock units in the basin that forms Moab Valley. Included in the bedrock units is the Glen Canyon Aquifer System, which is the principal source of ground water on the west side of the river.

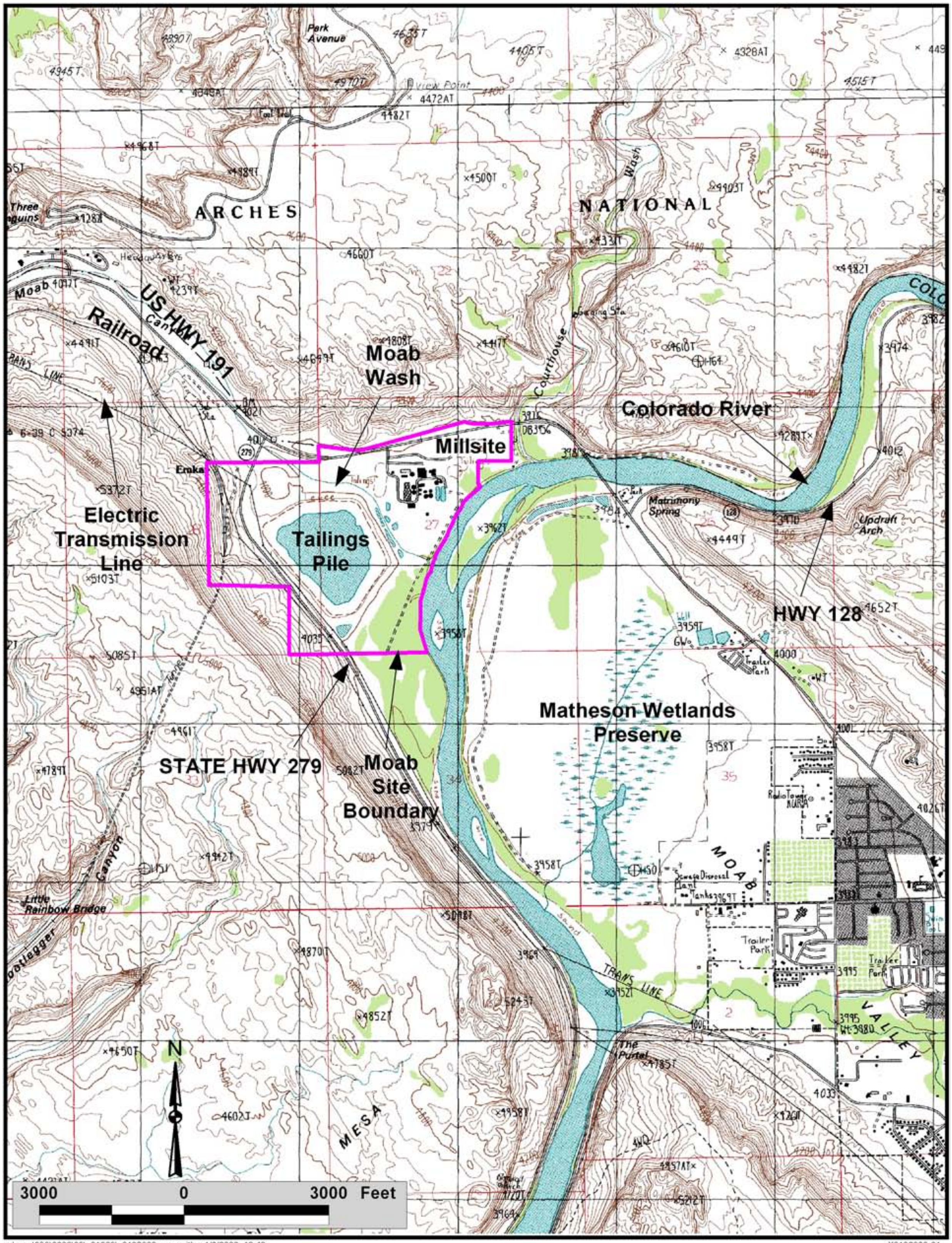

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Figure 1-1. Moab Site and Surrounding Area
(Modified from 1983 USGS Topographic Map)

The uppermost alluvial aquifer at the Moab site consists mostly of sediments referred to as basin fill. Ground water at greater depths in the aquifer is occupied by a highly saline water, and it often comprises brine (total dissolved solids [TDS] concentration greater than 35,000 mg/L). Underneath the river, upconing of salt water brings the brine close to riverbed elevation. To the west, the brine layer of less salty water becomes thicker with distance from the river. Most of the fresh water in the alluvial aquifer enters the Moab site from the northwest via Moab Wash and along geologic contacts between the alluvium and the underlying west Glen Canyon Group. The bedrock in this area is highly fractured and faulted, presumably as a result of the collapse of the Moab anticline, which was caused by dissolution of the Paradox Formation that forms the salt core of the anticline.

The shallow alluvial aquifer underlying the Moab site is divided into four hydrochemical facies on the basis of salinity: (1) an upper freshwater facies with TDS concentrations less than 3,000 mg/L; (2) a slightly to moderately saline facies with TDS concentrations between 3,000 and 10,000 mg/L; (3) an intermediate facies of very saline water with TDS concentrations between 10,000 and 35,000 mg/L; and (4) a lower briny facies with TDS concentrations greater than 35,000 mg/L. All four facies existed beneath the site prior to milling activities. The deeper brine water results mostly from dissolution of the underlying salt beds of the Paradox Formation present beneath most of the site.

The fresh water entering the site from the northwest quickly becomes mixed with more saline water in the alluvial aquifer as it flows toward the Colorado River. Salinity naturally increases with distance from the freshwater source and also with depth below the water table. Mixing of the fresh water with the brine influences the background water quality at the site. The result is a background water quality in the alluvial aquifer that is highly variable both vertically and horizontally across the site.

Site ground water containing 3,000 mg/L or less TDS occurs in a limited area located upgradient of the of the tailings pile near where Moab Wash empties out at Moab Canyon. Although some of the TDS in the ground water system is from tailings pile leachate, the percentage of the aquifer that would contain TDS concentrations of less than 3,000 mg/L after ground water remediation would be minimal.

The Colorado River is located along the east boundary of the Moab site and is the only significant surface water feature associated with the site. The uppermost aquifer naturally discharges to the Colorado River. The ground water contamination contained within this discharge represents a potential threat to aquatic life present in the river.

Section 5.0 of the final EIS provides a detailed description of the surface water and ground water hydrology for the Moab site.

1.3 Ground Water Contamination

Because most of the ground water in the uppermost aquifer has naturally occurring TDS concentrations exceeding 10,000 mg/L, the aquifer meets the definition of a limited-use aquifer as described in the U.S. Environmental Protection Agency's (EPA) *Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy* (EPA 1998). As a consequence, the aquifer beneath the Moab site does not represent a potential source of drinking water.

In addition to the TDS levels in the site ground water, other site-related chemical constituents appear to be mostly the result of historical uranium-ore processing activities. These constituents were assessed for their potential human health impacts on the surface water in the Colorado River. Calculations show that no unacceptable human health risks would be expected for most probable uses of river water. Appendix D of the final EIS provides details of the human health risk evaluation. The compliance strategy for remediation of the Moab site ground water focuses on being protective of the ecological receptors (i.e., endangered fish) and achieving compliance goals (i.e., surface water standards) in the surface water.

The screening process identified five contaminants of potential concern in ground water at the Moab site: ammonia, copper, manganese, sulfate, and uranium. Ammonia is the key constituent driving the proposed ground water remedial action because of its high concentrations in tailings seepage, ground water, and its toxicity to aquatic organisms. During milling operations, the tailings contained fluids with TDS concentrations ranging from 50,000 to 150,000 mg/L. The high salinity of these made them sufficiently dense to migrate vertically downward through less saline water and into the brine. This deep migration is believed to have created a reservoir of ammonia that now resides below the uppermost surface of the brine (brine surface) observed today. The ammonia below the brine surface appears to have come to rest at an elevation where it was buoyed by brine having a greater density than the ground water containing the ammonia. Under present conditions, the ammonia plume beneath the brine surface represents a potential long-term source of ammonia to the overlying ground water system. The conceptual model presented in Figure 1-2 illustrates this ammonia source at the brine interface (basal flux), the legacy ammonia plume, and residual seepage of ammonia from tailings pore fluids.

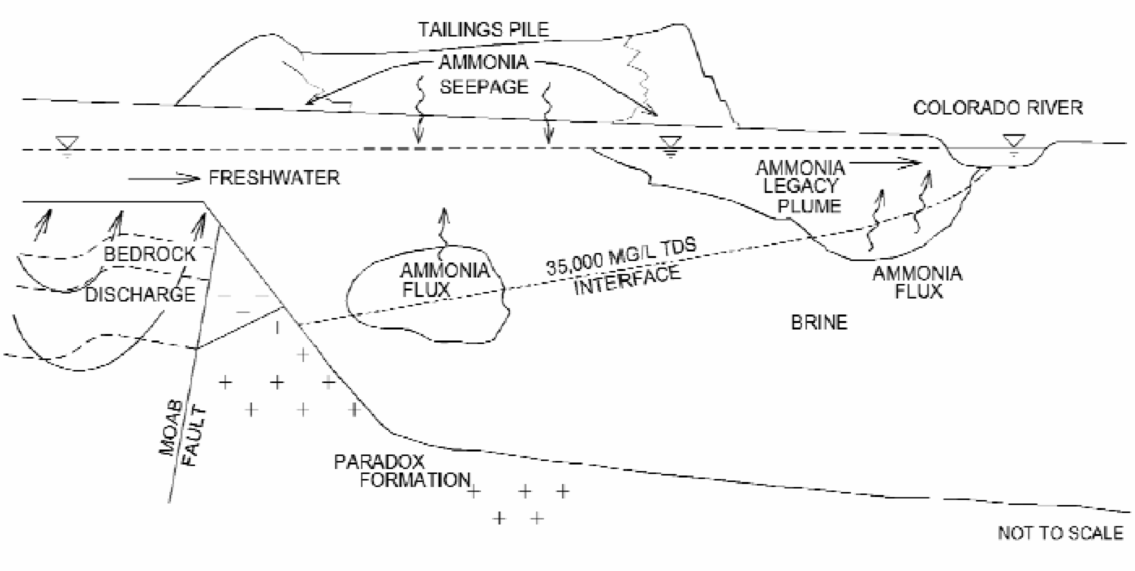

Figure 1-2. Conceptual Model, Saltwater/Freshwater Interface

As described in Section 2.3 of the final EIS, modeling has predicted that concentrations of the other four contaminants of potential concern would reach acceptable concentrations in surface water due in part to projected seepage rates and naturally occurring dilution. Therefore, it is assumed that if ammonia target goals could be achieved that are acceptable for protection of aquatic life, concentrations of the other four contaminants of potential concern would also be protective. Even though the geochemical behavior of the other contaminants of potential concern differs from that of ammonia, it is anticipated that concentrations of these constituents would decrease to protective levels in the same time frame that it would take for ammonia to reach protective levels because their concentrations are less elevated above applicable remediation criteria (e.g., surface water standards), the contaminants are less widespread, or they occur at elevated concentrations less frequently.

1.4 Existing Ground Water Quality

In 2004, additional ground water quality data for the Moab site were collected (DOE 2005b). In the area lying between the tailings pile and the river, ammonia concentration ranged from 500 to 1,700 mg/L and averaged approximately 900 mg/L as nitrogen (see Table 1–1). TDS concentrations ranged from 10,000 to 56,000 mg/L and averaged approximately 24,000 mg/L. The average uranium concentration was 2.7 mg/L with a range between 1.9 and 4.0 mg/L. The average pH was 6.8 with a range of 6.11 to 7.02. Well-specific water chemistry information is presented in Appendix A. The values shown in Table 1–1 represent the basis for the remediation systems presented in this document.

Table 1-1. Design Ground Water Chemistry

Parameter	Average Concentration	Minimum Concentration	Maximum Concentration
Ammonia as N, mg/L	900	500	1,700
pH	6.8	6.11	7.02
Total Dissolved Solids, mg/L	24,000	10,000	56,000
Uranium, mg/L	2.7	1.9	4.0

1.5 Current Ground Water Treatment Process

Contaminated ground water is currently being treated at the Moab site by pumping the water through a number of extraction wells to an evaporation pond located on top of the tailings pile and by injecting Colorado River water into a series of wells. The extraction/injection wells are located near the west bank of the Colorado River in three configurations. Contaminated ground water from extraction wells in Configurations 1 and 3 is pumped through a common pipeline to the evaporation pond. When first constructed, Configuration 2 wells were also pumped, and the extracted water was delivered to the evaporated pond. Currently, the Configuration 2 wells are used for injection of fresh water diverted from the river.

A sprinkler system is used on the tailings pile to enhance evaporation of the contaminated water. Flow meters are used at each of the extraction wells to monitor pumping rates, and totalizing meters record cumulative flows originating in the respective configurations. A staff gauge in the evaporation pond tracks levels that change in response to incoming flows and evaporation losses.

Configuration 1 wells were installed approximately 100 feet (ft) from a steep bank that forms the west bank of the Colorado River during relatively high runoff periods. These wells intercept ground water that was contaminated by seepage from fluids in the Moab tailings pile. Spacing between the wells is about 25 ft. There are a total of 10 Configuration 1 extraction wells (well numbers 470–479) and 25 observation wells and piezometers for monitoring aquifer responses to pumping and other hydraulic stresses. The extraction wells are 4 inches in diameter and are installed to depths of about 21–25 ft below ground surface (bgs). Eight of the 10 wells are screened over identical intervals of 10.3 to 19.7 ft bgs, and the remaining two are screened over depths of about 9 to 24 ft bgs. The depths and screened intervals of the Configuration 1 observation wells vary so that information collected from them can be used to portray three-dimensional (3-D) responses of the alluvial aquifer and the Colorado River to ground water pumping.

Configuration 2 wells, which are designed for either injection or extraction, are located approximately 50 ft from the river. The intent of placing these wells closer to the river is to minimize the time for injected fresh water to reach backwater areas of the Colorado River near its west bank. Currently, freshwater injection is conducted to provide a hydraulic barrier that diverts the discharged water closer to the center of the river. The spacing between the Configuration 2 extraction/injection wells is approximately 30 ft.

There are a total of 10 Configuration 2 extraction/injection wells (well numbers 570–579), all of which have a casing diameter of 6 inches. Five of the Configuration 2 wells are considered shallow and are installed to a depth of 31.3 ft. The other five wells are classified deep wells and extend to a depth of 41.3 ft. All shallow extraction wells are screened between depths of 15 and 30 ft bgs, which places them noticeably deeper than Configuration 1 extraction wells (mostly screened between 10 and 20 ft bgs). The deep well screens span depths of 25 to 40 ft bgs. The shallow and deep wells alternate with one another along the well field; even-numbered wells are shallow, and odd-numbered wells are deep. A total of 19 observation wells and riverbed piezometers are used to monitor alluvial aquifer and Colorado River responses to freshwater injection in Configuration 2. All but three of the observation wells are classified as shallow; the screened intervals of most shallow monitor wells are between 10 and 20 ft bgs.

The deep wells were added to Configuration 2 for the purpose of ensuring that river water injected into extraction wells would spread laterally toward the river over a wide vertical interval. It was believed that injection of uncontaminated water in both shallow and deep wells would cause a larger portion of backwaters in the river to undergo more dilution of ammonia than would occur using shallow wells only. Greater mass removal of ammonia contamination during pumping was also surmised as being a possible benefit of using deep wells.

Configuration 3 wells, located approximately 75 to 100 ft from the river, can also be used for either extraction or injection. The 10 wells comprising this system are numbered 670–679. All 10 wells are completed to a depth of 45 ft bgs, and the well screens span depths of between 15 and 45 ft bgs. There are approximately 12 observation wells and riverbed piezometers in the Configuration 3 area monitoring alluvial aquifer and Colorado River responses to pumping or injection.

1.6 Screening Analysis for Ground Water Remediation Alternatives

DOE previously screened technologies that would be applicable for treatment of ammonia and other contaminants of concern in the Moab site ground water. These are described in detail in

Section 9.0 of the *Site Observational Work Plan for the Moab, Utah, Site* (SOWP) (DOE 2003b). The level of treatment identified in the screening analysis depended largely on the selected method of effluent discharge. Four preliminary discharge options were considered:

- Discharge to surface water
- Evaporation
- Deep well injection
- Shallow well injection

The following treatment options were considered during the screening process:

- Standard evaporation
- Enhanced evaporation
- Distillation
- Ammonia stripping
- Ammonia recovery
- Chemical oxidation
- Zero-valent iron
- Ion exchange
- Membrane separation
- Sulfate coagulation

The reader is referred to Section 9.0 of the SOWP for details concerning the screening of the alternatives listed above. Note that the treatment technologies that were considered were selected for their ability to treat for both ammonia and TDS as the primary constituents of concern. Further evaluation since the SOWP has demonstrated effectively that ammonia is the sole constituent of concern that requires treatment to meet appropriate ground water remediation standards. This conclusion stems partly from the fact that there are no likely human health risks associated with the ground water, and that ecological receptors in the form of endangered fish species present in the Colorado River are likely to be affected by the ammonia in the ground water. The treatment technology and effluent discharge pathway that are ultimately used at the site must ensure that levels and mass fluxes of ammonia reaching the river near its west bank are protective of the fish. The U.S. Fish and Wildlife Service (USF&WS) has determined that this protective level translates into an ammonia concentration in ground water of 3 mg/L or less. Thus, the ammonia treatment goal adopted for this study is 3 mg/L.

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2.0 Regulations Addressing Treated Ground Water Discharge

2.1 UMTRA-Related Regulations

Ground water remediation at the Moab site is part of the Uranium Mill Tailings Remedial Action (UMTRA) Project and is subject to requirements of UMTRCA. UMTRCA authorized DOE to stabilize, dispose of, and control uranium mill tailings and other contaminated materials at inactive uranium-ore processing sites in a safe and environmentally sound manner. Congress amended UMTRCA in 2000 to designate the Moab milling site as a processing site in accordance with Title I of UMTRCA.

EPA has implemented this act through the *Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings*, which is codified at Title 40 *Code of Federal Regulations* Part 192 (40 CFR 192). Subparts A, B, and C of 40 CFR 192 apply to the remediation and final disposition of contaminated materials, including ground water at the Moab site. These standards must be met in the uppermost alluvial aquifer, which is the most likely portion to be affected by the uranium-ore processing activities. The uppermost aquifer at the Moab site contains very saline water, including brine. Under the river, the brine layer approaches riverbed elevation and can be as thick as 400 ft. West of the river, the brine is overlain by a layer of less salty water which thickens toward the west. Because ground water in much of the uppermost aquifer has TDS concentrations exceeding 10,000 mg/L, the aquifer meets the definition of a limited-use aquifer as described in EPA's *Guidelines for Ground-Water Classification Under the EPA Ground-Water Protection Strategy* (EPA 1988).

Under the requirements of 40 CFR 192, subpart C, the uppermost aquifer meets the criteria to apply supplemental standards based on a classification of limited-use ground water. Supplemental standards are regulatory standards that may be applied when the natural background concentrations of certain constituents (in this case, TDS) exceeds normally applicable standards (e.g., maximum contaminant levels). Although the uppermost aquifer cannot be used for a public water supply, the use of supplemental standards still requires that the aquifer be protective of both human health and the environment. At the Moab site, contamination due to tailings must be managed in a manner that ensures protection of human health and the environment from that contamination. That is, if site-related contamination could cause an adverse effect on a drinking water source or a connected surface water body, management of contamination would be necessary to protect these resources.

Because there are no drinking water aquifers in the vicinity of the Moab site that can be affected by site-related contamination, ground water remediation focuses on protecting surface water in the Colorado River for beneficial use.

2.2 Ground Water Quality Regulations

In addition to the 40 CFR 192 standards, the State of Utah administers a ground water protection program that is implemented under Utah Administrative Rule R317-6. This rule establishes ground water standards and also provides requirements for ground water classification. Like EPA standards, Utah regulations provide for the use of alternate ground water standards if ground water can affect surface water bodies. As a consequence, establishing appropriate ground water cleanup standards may depend on the potential effects the ground water has on the surface water. In certain instances, State of Utah ground water regulations provide for establishing concentrations in ground water "in order to meet applicable surface water standards." Under these regulations, Moab site ground water is classified as a Class IV saline aquifer according to R317-6. This classification requires that management of the ground water be protective of human health and the environment. There are no specific numerical standards that apply to Class IV ground water.

2.3 Underground Injection Control

The State of Utah implements an underground injection control (UIC) program through Administrative Rule R317-7. This program regulates the subsurface injection of fluids to prevent impacts to underground sources of drinking water. There are five classes of underground injection wells. Ammonia-contaminated ground water extracted from the Moab site, if re-injected, would be subject to the Class V UIC requirements. There are a number of Class V subclasses of wells. Water injection at the Moab site falls under subcategory 5X26, Aquifer Remediation Related Wells, which deals with wells used to prevent, control, or remediate aquifer pollution at sites that include, but are not limited to, Superfund sites. The State of Utah requires Class V UIC permits and provides technical guidance and application materials in a permit application package, included as Attachment 1 of this report.

2.4 Surface Water Regulations

There are two issues affecting direct discharge of treated ground water to the Colorado River. First, the State of Utah has primacy to implement the Clean Water Act, which it administers through the Utah Pollutant Discharge Elimination System (UPDES) program under Administrative Rule R317-8. Second, since there are listed endangered species present in the Colorado River, any surface water discharge must be protective of those species and their critical habitats.

Under the UPDES program, direct discharges of treated ground water to the river require a permit issued by the State of Utah. A formal permit application containing the following information is required.

- Expected outfall locations
- The expected date of commencement of discharges
- Flows, sources of pollution, and treatment technologies
- Effluent characteristics (expressed in concentration and total mass) for conventional and effluent-specific parameters
- Engineering reports for the treatment system

Once issued, the UPDES permit includes prescriptive requirements for the following:

- Discharge limits for applicable effluent parameters
- Monitoring and reporting
- Operation and maintenance of the treatment system
- Recordkeeping

Specific discharge limits have been established for numerous categories of industrial wastewater effluents, including limits for uranium-ore mining/processing facilities, as invoked by reference under 40 CFR 440.32. However, since the Moab site is no longer actively processing uranium ore, these regulatory requirements do not apply to the site ground water.

In addition to UPDES permitting and effluent discharge limits, protection of endangered species in the Colorado River requires that shallow ground water discharging to the river meet certain standards. Specifically, USF&WS has established that an ammonia concentration of 3 mg/L must be achieved in shallow ground water to be protective of the listed species present in the river near the Moab site.

2.5 Endangered Species Act

Removal of ammonia from ground water is necessary to prevent elevated levels of this constituent from adversely impacting endangered fish species in backwaters near the river's west bank. Likewise, shallow injection of treated ground water must also meet concentration levels protective of the endangered fish. In accordance with Section 7 (Interagency Cooperation) of the Endangered Species Act, consultation with USF&WS is necessary to ensure that the discharge is unlikely to adversely affect those species. This consultation has established that the protective concentration for ammonia in ground water discharged to the Colorado River is 3 mg/L. This limit applies to both direct discharge of treated ground water to surface water and injection of treated water into shallow ground water. The 3-mg/L limit applied to the injected water is intended to be conservative, such that there is no potential for exceeding surface water standards.

End of current text

3.0 Ground Water Remediation Objectives

Ammonia is the primary constituent of concern at the Moab site and the sole constituent that is expected to require treatment. Four other contaminants of potential concern (sulfate, copper, manganese, and uranium) are also present in the local aquifer. Because the aquifer is not considered a source of drinking water, and modeling has shown that there is no human health risk associated with ammonia present in the aquifer, the focus of ground water treatment is protection of the backwaters in the Colorado River located along its west bank. The discharge of ammonia-contaminated ground water to the river has the potential to adversely affect fish species in the river. Of particular concern is the presence of several species listed as endangered under the Endangered Species Act. The primary objective of remediation at the Moab site is protection of the Colorado River. Over the long-term, project objectives call for removal of contaminant mass such that contaminant concentrations are reduced to acceptable levels.

The concentration of ammonia (as nitrogen) in Moab site ground water near the river ranges from 500 to 1,700 mg/L and averages about 900 mg/L. Regardless of whether the treated ground water is injected into the upper zone of the aquifer or is discharged directly to the river, current plans call for the ammonia concentration to be reduced to a maximum of 3 mg/L. The 3-mg/L limit has been deemed adequate by USF&WS for protecting the Colorado River near the river's west shoreline. Additional ground water modeling to determine the impacts of the ammonia ground water plume on the river would be helpful.

End of current text

4.0 Methods Considered for Alternatives Development

This section discusses ground water collection options and provides further evaluation of the alternatives that were identified for analysis in previous studies (DOE 2003a). The treatment technologies that will be further addressed in the alternatives analysis section are also identified.

4.1 Ground Water Extraction

Most approaches to long-term remediation of ground water at the Moab site make use of extraction wells that capture ground water containing ammonia before it flows to the Colorado River.

4.1.1 Existing Extraction Wells

The Ground Water Interim Action (Ground Water IA) (DOE 2005b) has been operational since 2003. This Interim Action consists of three components, or configurations. Configuration 1 and Configuration 3 each consist of 10 wells to provide extraction of ground water. The 10 wells in Configuration 2 are currently being used to inject clean river water into the subsurface near the Colorado River. These 30 existing wells could continue to be used for long-term ground water remediation at the Moab site. Pumping rates at Configuration 1 wells suggest that an average per-well discharge rate of 2.5 gallons per minute (gpm) is capable of reducing ammonia concentrations in the surface water near the west bank of the Colorado River. Exact reasons for this observation have yet to be fully determined, but pumping of river water by the extraction wells appears to be a major factor. Ongoing site activities include examining hydraulic processes that may be contributing to ammonia attenuation.

4.1.2 Additional Extraction Wells

Examination of the area of influence of the existing wellfield and the breadth of the ammonia plume located downgradient of the Moab tailings pile indicates that a total of 60 extraction wells would be needed to eliminate adverse impacts to the Colorado River. Assuming a per-well extraction rate of 2.5 gpm, the design flow rate then becomes 150 gpm, signifying that additional ground water extraction wells are needed. For the alternatives analysis, it was assumed that all 30 existing wells in Configurations 1, 2 and 3 could be used for extraction, and that 30 new wells with an average discharge rate of 2.5 gpm/well would be needed for the long-term remediation of ground water at the Moab site.

4.2 Evaluation of In Situ Treatment Methods

Previously, a preliminary screening of technologies was completed that addressed treatment of ammonia and TDS in contaminated ground water at the Moab site (DOE 2003a). Subsequent to the preliminary screening, the final EIS (DOE 2005a) was completed. The final EIS indicated that ammonia was the key constituent driving the proposed ground water remedial action because of its high concentrations in the tailings seepage and ground water and its toxicity to aquatic organisms. Data collected thus far under the Ground Water IA indicate that protective surface water concentrations could be achieved by meeting less conservative goals than chronic standards in ground water. In this study, a target goal of 3-mg/L concentration of ammonia in ground water is used to evaluate ground water cleanup alternatives. The potential prescreened technologies for in situ ground water treatment are discussed in greater detail in this section.

4.2.1 Phytoremediation

Phytoremediation is a treatment technology that uses deep-rooted plants that either extract certain contaminants from ground water through root uptake or stimulate biodegradation of dissolved constituents. Phytoremediation systems for ammonia treatment usually use some variation of the wetland treatment (Kadlec 1995) or natural treatment (Metcalf & Eddy 1991) approach. These systems have not been used where the influent ammonia concentration is more than 40 mg/L (Metcalf & Eddy 1991). Phytoremediation applications are limited to the depths that are within the reach of the plant roots. Existing extraction wells in the Ground Water IA at the Moab site are recovering ground water at a depth of 12 ft to 20 ft bgs, a depth that is beyond the reach of many plant roots. However, the phreatophyte species tamarisk (*Tamarix ramosissima*) has demonstrated the capacity to survive at the Moab site where such depths to ground water are observed. A site-specific issue to consider when evaluating the feasibility of phytoremediation in the ground water is the range of TDS concentrations. In most cases, TDS concentration exceeding 24,000 mg/L is unacceptable for, and would preclude the use of, phytoremediation (Scherer 1996). At the Moab site, a study was conducted using existing tamarisk in contaminated areas. The results showed that tamarisk stands growing in areas with greater than 1,000 parts per million (ppm) ammonia in ground water samples are stressed and dying. Tamarisk stands growing in areas with 100 ppm to 500 ppm ammonia in the ground water were also unhealthy (Waugh 2003). As a consequence, phytoremediation is not considered in the alternatives analysis.

4.2.2 Permeable Reactive Barriers

A permeable reactive barrier consists of a subsurface permeable zone of appropriate reactive material that is placed across the path of a contaminant plume. As contaminated ground water moves through the barrier, the contaminants are removed or degraded (Nyer 1996). Because permeable reactive barriers have not been used to treat ammonia-contaminated ground water, they are not evaluated in the alternatives analysis.

4.2.3 In Situ Stabilization

Stabilization is conducted by mixing contaminated soil with additives to produce a cement-like mass. In situ stabilization is implemented by applying the same stabilization technology to the soil as used in an ex situ process (Nyer 1996). Although stabilization is commonly applied to soil contaminated with heavy metals and other inorganic compounds that can be immobilized in the soil, it has not been used to treat ammonia-contaminated ground water. Also, high-salinity water can interfere with cement-based processes by increasing set time or requiring different types of Portland cement (Means et al. 1995). For these reasons, in situ stabilization treatment is not considered in the alternatives analysis.

4.3 Evaluation of Ex Situ Treatment Technologies

An ex situ treatment technology is any water treatment technology that reduces ammonia after ground water has been extracted and pumped into a land-surface treatment facility.

4.3.1 Distillation

In distillation, a solution is evaporated by heating it to its boiling point and supplying additional heat for evaporation. Condensation of the water vapor produces TDS-free water as nonvolatile contaminants (such as inorganic salts) remain in solution. A concentrated liquor or brine is produced, which has to be removed from the evaporation chamber. This brine, which constitutes approximately 10 percent of the influent water, would need to be further managed in evaporation ponds or injected into the subsurface (DOE 2003a). Although distillation is capable of reducing ammonia concentration in water, other technologies are more cost-effective. Distillation is not a consideration in the alternatives analysis.

4.3.2 Coagulation/Flocculation

This treatment option was considered in the Screening Level Analysis (DOE 2003a) because it could reduce TDS by reducing sulfate concentrations. It was effective in reducing sulfate but did not achieve the desired effect on TDS. With the objectives for ground water treatment focused on ammonia reduction, coagulation/flocculation is not considered in the alternatives analysis.

4.3.3 Ion Exchange

Ion exchange is a process used to remove ammonia (Culp 1978) in cases where the ammonia concentration is less than 100 mg/L. Porous zeolite (clinoptilolite and sepiolite) can be used for selective sorption of ammonia. The ammonia-contaminated water is passed through the porous medium until the medium is saturated with the contaminant. At this point the ammonia-saturated medium can be regenerated by air stripping or by chemical treatment (DOE 2003a). Because full-scale application of this technology has been used successfully for ammonia treatment, it is included in the alternatives analysis as a secondary treatment process.

4.3.4 Chemical Oxidation

Ammonia represents the most reduced form of nitrogen; consequently, it is susceptible to chemical oxidation, the product of which is nitrogen gas. Different chemical oxidizers can be used, such as chlorine, ozone, or potassium permanganate. Each chemical oxidizer has specific requirements (e.g., pH, reaction time, required doses). Also, different by-products are generated, depending on the selection of the chemical oxidizer. For example, chlorination of ammonia produces hydrochloric acid (which, depending of the resulting pH, might need further neutralization). Because the costs of chemical reagents associated with ammonia oxidation are considered high, this technology is often used as a polishing step that follows other ammonia technologies that only achieve partial treatment (DOE 2003a). Chlorine residuals resulting from ammonia oxidation by chlorine can be toxic to aquatic species. In many cases, sulfur dioxide can be used to effectively remove such chlorine residuals. Because of the very high concentrations of ammonia present in the ground water and the potential for generating significant mass of by-products, this technology is not evaluated further in the alternatives analysis.

4.3.5 Biological Nitrification

Biological nitrification is particularly applicable to cases where ammonia removal is desired, but complete nitrogen removal is not required (EPA 1993). The nitrification process is carried out by bacterial populations that sequentially oxidize ammonia to nitrate with intermediate formation of nitrite. The two principal genera of importance for carrying out this process are *nitrosomonas* and *nitrobacter*. Both of these groups are classified as autotrophic organisms because they derive energy for growth from the oxidation of inorganic nitrogen compounds. Another feature of these organisms is that they use inorganic carbon for synthesis rather than organic carbon. Since complete nitrification is a sequential reaction, treatment process systems must be designed to provide an environment suitable for the growth of both groups of nitrifying bacteria. Nitrification requires at least 10 times the amount of alkalinity in the water, as ammonia and pH must be controlled closely. One potential concern with nitrification is the high TDS concentration. O'Reilly (2003) has demonstrated that rates of nitrification tend to increase from freshwater to saltwater sites. Because the rates are higher with increased TDS, nitrification may be an effective treatment approach at the Moab site. However, when ammonia concentrations are greater than 150 mg/L, the nitrification process can be inhibited. Assuming that the ammonia can be reduced to this level through dilution, nitrification appears to be a feasible treatment technology and is considered further in the alternatives analysis.

4.3.6 Ammonia Stripping

Because ammonia is a volatile substance (DOE 2003a), mixing of ammonia-containing water with ambient air (aeration) will result in ammonia volatilization (stripping). Various methods have been used for ammonia stripping, including packed columns (stripping towers) and ponds. Ammonium is an ion that is in equilibrium with dissolved ammonia gas, the latter of which represents the uncharged, volatile form of ammonia. This equilibrium is controlled by the acid-base conditions of the aqueous solution, as characterized by pH. Ammonia stripping requires pH adjustment from values close to neutral (pH 6–8) to pH values of 9−10.5. Because pH adjustment in conjunction with air-stripping technology for ammonia treatment has been used successfully, it is included in the alternatives analysis.

4.3.7 Ammonia Recovery

The precipitation of ammonia and phosphate in the form of struvite (magnesium ammonium phosphate [$MgNH_4PO_4 \cdot 6H_2O$]) has been considered to treat numerous wastewaters, including drug-processing, yeast production, and tannery waters. The process consists of adding near-stoichiometric amounts of magnesium and phosphate salts (most likely as magnesium hydroxide and sodium phosphate) into water that has a pre-adjusted pH between 8 and 10, at which solubility of the struvite is the lowest. After precipitation, the formed solids are separated by a solid-liquid separation process, such as media filtration (contact clarification) or flocculation-sedimentation. This option, which requires purchase of process chemicals (magnesium and phosphate salts, as well as chemicals required for pH adjustment), does not provide complete ammonia removal. Therefore, it is likely that one or more polishing steps with another ammonia-treating technology would be required at the Moab site. Also, the potential for radiological contamination of any recovered ammonia prohibits the recycling of the recovered ammonia. Therefore, this technology is not evaluated further in the alternatives analysis.

4.3.8 Evaporation

Solar evaporation has been demonstrated at the Moab site by pumping contaminated ground water into a large double-lined outdoor pond located above the 100-year floodplain and on the tailings pile (DOE 2003a). This technology treats extracted ground water by allowing the water to evaporate in response to warm temperatures during part of the year. Nonvolatile contaminants are contained and allowed to concentrate for later disposal. Evaporation can also be used to treat concentrated wastewater from treatment processes such as distillation and ion exchange that produce a wastewater stream. Passive evaporation does not require any mixing of water after disposal in the ponds. And evaporation rates can be increased considerably by using devices such as spray nozzles, but at additional costs. If applied at the Moab site, this treatment option would require provisions for disposal of the solids accumulated in evaporation ponds. Because this technology has been used successfully by DOE at multiple sites, and because it is a commercially available treatment technology, it is evaluated further in the alternatives analysis.

4.4 Ground Water Disposal Methods

After ground water has been extracted and treated by technologies other than evaporation, the ground water requires disposal, presumably by one of the following methods.

- Shallow alluvial aquifer injection where the TDS concentration is less than 35,000 mg/L
- Injection into or beneath the Paradox Formation
- Injection into the alluvial aquifer where the TDS concentration is greater than 35,000 mg/L
- Direct discharge into the Colorado River

The conceptual model of subsurface hydrogeology at the Moab site (Figure 1–2) shows a brine surface that demarcates the location of a brine TDS concentration of 35,000 mg/L. The TDS distribution with depth below the water table in the area between the tailings pile and Colorado River typically follows a distinct pattern in reference to the brine surface. At shallow depths above the brine surface, TDS concentrations grade typically from about 5,000 to 10,000 mg/L at the water table, to 35,000 mg/L at the brine surface. Below the brine surface, TDS concentrations increase gradually to levels of about 80,000 to 100,000 mg/L.

4.4.1 Shallow Aquifer Injection

If the option of water injection into the shallow aquifer containing non-brine ground water were selected, delivery of the water can be accomplished using either injection wells or infiltration galleries. It is assumed that this option would only require treatment of ammonia prior to the treated water's return to ground water. Since the treated water would eventually reach the Colorado River after injection, ammonia concentrations would be required to meet the USF&WS criterion of 3 mg/L for protection of endangered fish species. Injection wells are considered a technically viable approach and are considered further in the alternatives analysis.

Infiltration galleries are an alternative to injection wells, and facilitate percolation of treated water through the soil composing the vadose zone. Infiltration galleries are considered technically viable and are considered further in the alternatives analysis.

4.4.2 Injection Into or Beneath the Paradox Formation

The Paradox Formation is estimated to lie more than 400 ft bgs at portions of the Moab site where injection into or beneath the Paradox Formation would be considered. In addition, the formation appears to be as thick as 8,000 ft. If this option were selected, extracted ground water would be disposed of using a new deep injection well system that could be as shallow as 500 ft bgs and possibly as deep as 8,000 ft bgs. This option would not require treatment of ammonia, and is considered a viable approach that is evaluated further in the alternatives analysis.

4.4.3 Injection Into the Alluvial Aquifer Where TDS Concentration is Greater Than 35,000 mg/L

Since the depth of the brine surface is relatively small close to the river, injection into the brine in the alluvium is considered a viable technical approach that would be subject to regulatory approval. The final EIS (DOE 2005a) identified claims by stakeholders that ground water may be migrating eastward from the Moab site into the Matheson Wetlands Preserve located across the Colorado River. For this reason, it is questionable whether injection into brine portions of the alluvial aquifer would be approved by regulators. Therefore, this disposal method is not considered further in the alternatives analysis.

4.4.4 Direct Discharge to the Colorado River

The Colorado River constitutes the natural discharge site for contaminated ground water at the Moab site. Because of water quality standards and designation as critical habitat for endangered fish, direct discharge of treated water would require extensive water treatment for ammonia and TDS reduction. Also, if discharge to the river was considered a viable alternative for dealing with treated effluent, appropriate permits would need to be obtained from the State, and compliance with conditions such as discharge rates and effluent composition would be required. As a consequence, this discharge option is not evaluated further in the alternatives analysis.

4.5 Water Injection Using the Colorado River

Results from Configuration 2 freshwater injection (DOE 2005b) between October 2004 and October 2005 indicate that measured ammonia concentrations in surface water near the west bank of the Colorado River can be reduced by freshwater injection, and therefore should be considered in the alternatives analysis. Water injection can be accomplished at the Moab site using injection wells, infiltration galleries, constructed wetlands, or spreading basins. For all four injection methods, Colorado River water would be stored in a river water storage pond and then pumped to the injection/infiltration system. The river water storage pond would provide settling of sands and silts and other debris from the river as well as surge capacity for pumps.

4.5.1 Well Injection

As discussed in Section 4.4.1, if Colorado River water injection into the shallow aquifer were selected, delivery of the water can be accomplished using injection wells. Since the ammonia concentration in the Colorado River upstream of the injection location meets the USF&WS criterion of 3 mg/L for protection of endangered fish species, the water would not require treatment. Injection wells are considered a technically viable approach and are considered further in the alternatives analysis.

4.5.2 Infiltration Galleries

As discussed in Section 4.4.1, if Colorado River water injection into the shallow aquifer were selected, delivery of the water can be accomplished using infiltration galleries. Since the ammonia concentration in the Colorado River upstream of the injection location meets the USF&WS criterion of 3 mg/L for protection of endangered fish species, the water would not require treatment. Infiltration galleries are considered a technically viable approach and are considered further in the alternatives analysis.

4.5.3 Constructed Wetlands

If Colorado River water injection into the shallow aquifer were selected, another technology that can be used for delivery of the water is constructed wetlands. Since the ammonia concentration in the Colorado River upstream of the injection location meets the USF&WS criterion of 3 mg/L for protection of endangered fish species, the water would not require treatment. Constructed wetlands are considered a technically viable approach and are considered further in the alternatives analysis.

4.5.4 Spreading Basins

If Colorado River water injection into the shallow aquifer were selected, another technology that can be used for delivery of the water is spreading basins. Since the ammonia concentration in the Colorado River upstream of the injection location meets the USF&WS criterion of 3 mg/L for protection of endangered fish species, the water would not require treatment. Spreading basins are considered a technically viable approach and are considered further in the alternatives analysis.

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5.0 Analysis of Subsystem Components for Achieving Ground Water Remediation Objectives

Most of the remediation alternatives examined consist of three subsystems: ground water extraction, water treatment, and effluent disposal. General characteristics and components of these subsystems are described below. Subsequently, distinct alternatives composed of the subsystems are identified and discussed.

Each subsystem is described and assessed with regard to the following issues:

- Subsystem components and spatial requirements
- Capacity to achieve remediation objectives in ground water and the Colorado River
- Capital cost
- Operations and maintenance (O&M) cost
- Safety considerations
- Implementation factors and limitations

Consideration of each of these issues generally involved the development of conceptual designs. Each conceptual design took into account factors such as desired flow rate and expected ground water and/or Colorado River water quality. When applicable, conceptual designs were based on existing performance data from the Ground Water IA (DOE 2005b).

The capital costs associated with conceptual designs were based on standard construction methods and standard unit prices as obtained from handbooks (e.g., Means 2004) and vendor quotes. Each capital cost allowed for a for a 30 percent contingency in conformance with DOE Project Management Practices (DOE 2000).

The O&M costs are assumed to account for labor, energy, and/or chemical costs. The labor cost is assumed to be $65,000 per employee per year, electrical energy costs are based on $0.057 per kilowatt-hour, and chemical costs are derived from vendor quotes. Safety considerations include safety levels required for construction, the associated effects on labor productivity (Means 2004), and qualitative estimates of safety risk to O&M workers. Additional factors such as the need for pilot plants or computer modeling are also identified.

5.1 Extraction Wells Subsystem

Twenty extraction wells and 10 injection wells comprise the current form of the Ground Water IA at the Moab site. The extraction wells in Configuration 1 are currently pumped at an average rate of about 2.5 gpm. The per-well extraction rate of the Configuration 3 system is significantly larger, which is mostly attributed to different construction used for these wells. For extraction, the existing 10 Configuration 2 wells used for injection will be converted to use for ground water extraction. The relative success of Configuration 1 wells in inducing infiltration of river water and concomitant recharge of local ground water (DOE 2005b) suggests that an average per-well pumping rate of 2.5 gpm is sufficient for meeting water quality criteria in the river.

Assuming that each well in an extraction system located just west of the river was pumped at an average rate of 2.5 gpm, 60 wells would be required to intercept the ammonia plume stemming from the tailings pile. This would result in a design flow rate of 150 gpm and require that 30 new extraction wells be constructed.

It is assumed that each new well will be 6 inches in diameter and would be drilled approximately 30 ft bgs using the same drilling methodology applied to the Configuration 3 area. Twenty of the new extraction wells would be spaced on 25-foot centers in an area south of Moab Wash where it discharges into the Colorado River, and the remaining 10 new extraction wells would be constructed south of Configuration 1. The spacing for these latter 10 wells would be about the same as that used for existing extraction wells (25 to 30 ft). Each well would be constructed from Schedule 40 polyvinyl chloride (PVC) pipe and include a 15-foot screened interval in the bottom 15 ft of the well. In addition, each well annulus would be sealed with concrete and bentonite.

A surface pad and protective enclosure would be constructed for each extraction well. After construction of the wells, each well would be developed and slug-tested prior to the installation of a 4-inch 1/3 horsepower (hp) submersible pump and associated valves and fittings such that the pump is capable of discharging 2.5 gpm. One set of ammonia and uranium samples would be collected and analyzed for each new well. Estimated capital and O&M costs for the 30 new wells are presented in Appendix B–1. The O&M costs for the extraction wells include two full-time equivalents (FTEs) and the electrical energy used by the 60 1/3 hp pumps.

5.2 Treatment Subsystems

5.2.1 Evaporation Pond System

The proposed evaporation pond system is a solar-enhanced, double-lined pond system that has been sized using performance data for the existing evaporation pond system that was constructed on the tailings pile. The pond system uses spray enhancement where the perimeter of the evaporation pond is designed to have a 10:1 (horizontal to vertical) side slope; water is sprayed to effectively reduce the size of the evaporation pond system in comparison to a passive solar evaporation pond. The pond is lined using layers of geosynthetic materials, with the top layer consisting of 40-mil-thick, unreinforced, high-density polyethylene. The second layer is the primary geosynthetic clay liner that overlies the leak detection layer. The leak detection system consists of a geocomposite liner designed to collect and transport any leakage for collection and management. The bottom layer is the secondary geosynthetic clay liner that is placed over the prepared soil surface of the evaporation pond. Estimated capital and O&M costs for the proposed evaporation pond system are presented in Appendix B–2.

Design of the evaporation pond system takes into account measurements of local evaporation and precipitation rates. This results in the development of two evaporation ponds, both of which would be in service without any redundancy, operational issues, or problems. Each pond has a lined area that is 565 ft wide by 1,700 ft long, for a total of 22.1 acres per pond. The depth of each pond takes into account the water storage volume for a 100-year storm event, net water volume resulting from annual precipitation and evaporation, storage of precipitated solids due to evaporation, and freeboard requirements. The design provides adequate apron area for spray-enhanced evaporation. Consideration of these factors results in a design pond depth of about 8 ft.

5.2.2 Ammonia-Stripping Treatment

Air stripping of ammonia from extracted ground water includes processes to adjust the water pH so that all ammonium ions can be converted to ammonia vapor. Ammonia stripping is the initial component of the treatment process in which extracted ground water is subsequently treated by catalytic oxidation to achieve the remedial action objective of 3 mg/L NH_3-N or less.

The ammonia stripping design includes a storage tank for accumulating the ground water pumped from the aquifer by extraction wells. Water is pumped from the storage tank directly to the air stripper unit. During typical operation, the water level in the tank is expected to remain fairly constant, with the water inflow from the extraction wells balanced by outflow to the air stripper.

The ground water storage tank consists of a 5,550-gallon, cone-bottom tank constructed of high-density polyethylene. Supported by a tubular steel stand, the tank provides 30 minutes of surge capacity for both the extraction wells and the air stripper due to changes in operation.

Two transfer pumps deliver water from the storage tank to the ammonia stripper. Both pumps are capable of providing 150 gpm. During normal operation, one pump is operated continuously, and the second pump is held in standby mode. If the first pump fails or requires maintenance, the second pump continues to supply water to the air stripper for treatment. Estimated capital and O&M costs for the air stripper system are presented in Appendix B–3.

5.2.2.1 Air Stripper

Prior to entering the air stripper, the pH of the extracted water is increased from a value of about 6.8 up to 11. This adjustment drives the equilibrium between dissolved ammonium and ammonia gas to a point at which the dissolved gas becomes the predominant form of ammonia. The pH increase takes place in chemical storage tanks containing sodium hydroxide solution (25 weight percent). Metering pumps are used to add the sodium hydroxide solution to influent water, a static in-line mixer homogenizes the mixture, and sensors keep track of pH and temperature. The sodium hydroxide storage tank is similar to the tank used for storage of extracted ground water. Consumption of the sodium hydroxide solution is estimated at approximately 35 gallons/day.

Sodium hydroxide was selected for increasing pH because (1) it is the most widely used alkaline chemical in industry; (2) it is available in various concentrations, making it easy to use; (3) sodium is present in the Moab site ground water as a major constituent; and (4) the salts containing sodium, upon neutralization, are normally soluble in water. It should be noted that 50 percent sodium hydroxide solution freezes at temperature of 55–60 °F (13–15 °C). For this reason, 25-weight percent solution was selected for determining the volumetric quantities required for pH adjustment. The freezing point temperature for 20 percent sodium hydroxide solution is 14 °F (–10 °C).

After pH adjustment, the water stream is pumped through a heat exchanger located on the catalytic oxidizer to raise the temperature of the water to approximately 110 °F. As discussed previously, the increases in pH and temperature provide better efficiency for removal of the ammonia from the extracted water. The heated water is then routed to the top of the air stripper tower where it is distributed equally over the tower packing surface. A blower at the bottom of the stripping tower propels the airflow counter-current to the water stream in the tower. The tower packing distributes the water flow to allow intimate contact between water and air, which provides a high surface area for mass transfer of ammonia from the water stream to the air stream.

The design rate of water flow delivery to the stripping tower is 150 gpm, and the design airflow rate is 15,000 cubic feet (ft^3) per minute. A 7.5-hp centrifugal pump and a 30-hp blower provide the motive forces for the water and air streams, respectively.

The air stripper consists of a 10-ft-diameter column that is 42 ft in height. The tower contains 30 ft of packing media to distribute the water and provide high surface area that contacts both the air and water streams. The air stripper is constructed of fiberglass and includes a 60-inch air inlet/outlet, 3-inch ground water inlet, 6-inch ground water drain, and a 20-inch man-way. The tower packing is 2 inches in size (Hi-Flow type packing) and is constructed of polypropylene. The total pressure drop across the system does not exceed 12 inches of water. The design basis for the air stripper is an ammonia inlet concentration of 900 mg/L and a stripper efficiency of approximately 93 percent. This results in the ground water effluent having an ammonia concentration of approximately 63 mg/L. The effluent from the air stripper is treated further in a subsequent treatment unit.

Design calculations for ammonia removal using air stripping are normally performed for ideal systems; that is, the design is based on values for pure water. Values for other water sources, such as the high TDS ground water at the Moab site, can vary unpredictably. Consequently, treatability studies are advised for developing explicit design criteria for air strippers at the site.

5.2.2.2 Catalytic Oxidizer

The catalytic oxidizer unit consists of a reaction chamber, which contains a natural gas burner and a catalyst bed, and a heat exchanger for preheating the water supply to the air stripper. The system is skid-mounted and measures 9 ft wide by 25 ft long by 15 ft high. The ammonia/air stream exits the air stripper and is routed to the catalytic oxidizer reaction chamber. In the reaction chamber, the natural gas burner heats the ammonia/air stream to a temperature of approximately 550 °F (288 °C). The heated stream then enters the catalyst bed where the ammonia is converted to nitrogen gas and water vapor.

After exiting the reaction chamber, the hot air stream is used in an air-to-water heat exchanger to heat the water being fed to the air stripper. After exiting the heat exchanger, the air stream is discharged to the atmosphere through a stack.

5.2.2.3 Stripper Blowdown Storage Tank/pH Adjustment

The stripper blowdown storage tank accumulates the water that remains after ammonia has been removed in the air-stripping tower. This tank is identical to the ground water storage tank described in Section 5.2.2 and provides approximately 30 minutes of surge capacity. This tank supplies water to the ion-exchange system for final ammonia polishing prior to discharge.

5.2.2.4 Injection Well Storage Tanks

The injection well storage tank accumulates the treated water after ammonia has been removed in the air stripping tower. This combined tank and pump system is identical to the ground water storage tank described in Section 5.2.2 and provides approximately 30 minutes of surge capacity.

5.2.3 Ion Exchange

Ion exchange treatment is used to further treat extracted ground water to achieve the remediation objective of less than 3 mg/L ammonia. Before the ground water enters the ion-exchange unit, the pH is reduced from approximately 11 to a value of 7. The adjustment, in addition to being required for efficient operation of the ion exchange columns, returns the ground water to a neutral pH for eventual discharge into the environment. The pH adjustment system consists of chemical storage tanks containing sulfuric acid solution (93 weight percent solution), metering pumps for the addition of liquid sulfuric acid solution to the treatment stream, a static in-line mixer to homogenize the sulfuric acid with the stripper blowdown, and pH and temperature measurement elements. The sulfuric acid storage tank is similar to the tank previously identified for water storage and sodium hydroxide storage. The sulfuric acid consumption has been estimated at approximately 9 gallons/day.

Sulfuric acid is widely available in various concentrations and is the least expensive acid to use. The neutralization reaction with sodium hydroxide produces sodium sulfate salts and water. Sodium salts are normally soluble in water, and the Moab site ground water generally contains sodium and sulfates as major constituents.

The ion exchange unit operation consists of parallel ion exchange columns capable of handling flow rates of 75 gpm each. Each ion exchange column is 36 inches in diameter by 60 inches in height. Continuous operation of the ion exchange columns requires installation of redundant units, where one unit (two parallel ion exchange columns) is in operation for ammonia removal while the second unit is off-line for resin regeneration.

The calculated on-line operation for each ion-exchange unit is approximately 24 hours. Consequently, the ion exchange resins will require regeneration daily. Each ion exchange skid includes the manifold systems for regeneration of the ion exchange resin. It should be noted that vendors of ion exchange systems expressed concern about the high TDS concentrations in Moab ground water. The high salinity could result in decreased resin efficiency for ammonia removal as other cations compete for the available exchange capacity. Pilot treatability studies would be required to verify the exchange capability of various ion exchange resins for operation at the Moab site.

The ion exchange unit operation also requires tanks for storage of the fresh regenerant solution feed, spent regenerant solutions, and rinse water solutions. These tanks are identical to the tank systems previously described for ground water storage. The solution from the tanks is pumped using four centrifugal pumps that include valve manifolds for redundant pump service from any tank. It is anticipated that a zeolite or clinoptilolite will be used as the ion exchange medium, and a solution of 2- to 3-weight percent sodium chloride solution will be used to regenerate the ion exchange columns. Again, pilot treatability studies using Moab ground water will be required to confirm exchange capabilities and regeneration rates.

The spent regenerant and rinse waters will accumulate at a rate of approximately 3,500 gallons per day and will be fed to the air stripper for disposal. The 3,500-gallon per day accumulation equates to an additional 1.6 percent load duty on the air stripper. This should be well within the design capacity of the air stripper column and will eliminate the secondary waste associated with the regenerant and rinse solutions. Estimated capital and O&M costs for the ion exchange system are presented in Appendix B–4.

5.2.4 Nitrification Treatment for 150 gpm

Nitrification is an alternative to ion exchange treatment following air stripping. Air stripping reduces the ammonia concentration to a level at which nitrification can effectively reduce ammonia levels to less than 3 mg/L.

The conceptual design of the nitrification process is based on biological kinetics (Metcalf & Eddy 1991). The nitrification treatment process consists of two earthen basins, one for aeration and the other for sedimentation. The aeration basin is square (25 ft per side) and contains a single 20-hp surface aerator in its center. The aeration basin is approximately 12 ft deep, which allows for 2 ft of freeboard above 10 ft of water. A 10-ft-wide embankment with a 3:1 side slope forms the perimeter of the aeration basin to allow access of O&M activities.

The sedimentation basin consists of three zones—solids storage, settling, and freeboard. The basin is square (110 ft per side), approximately 12 ft deep, and has the same side slope as the aeration basin. The solids storage zone in this basin is 5 ft deep and requires solids removal once every 10 years. Two feet of freeboard are provided for in the sedimentation basin. Estimated capital and O&M costs for the 150-gpm nitrification treatment system are presented in Appendix B–5.

5.2.4.1 Nitrification Treatment for 900 gpm

An alternative means of treating extracted ground water by nitrification involves the blending of 750 gpm of Colorado River water with 150 gpm of ground water. This dilution produces an influent ammonia concentration of 150 mg/L or less, which increases the efficiency of nitrification (EPA 1993). This treatment subsystem calls for using one 750-gpm pump to pump the extracted water into a nitrification/aeration basin, described below, with a standby pumping unit made available. The water pump is equipped with a 30-hp motor. The conceptual design for the 900-gpm system follows the same approach used for the 150-gpm nitrification system, with the nitrification process making use of an aeration and a sedimentation basin. The aeration basin is square (95 ft per side), and contains eight 30-hp surface aerators. It is approximately 12 ft deep, which allows for 2 ft of freeboard above 10 ft of water. A 10-ft-wide embankment with a side slope of 3:1 is located along the basin perimeter to allow access of O&M activities.

The sedimentation basin is square (265 ft per side) with the same 3:1 side slope and is approximately 12 ft deep. The solids storage zone within this basin is 5 ft deep and requires solids removal once every 10 years. This storage zone is overlain by a 5-ft-deep settling zone and 2 ft of freeboard.

An additional factor to address with this nitrification option is limited alkalinity (EPA 1993). The alkalinity concentration of the combined ground water and river water is inadequate for sustaining the nitrification process. Additional alkalinity is added to the influent in the form of sodium carbonate to make up for the alkalinity shortfall. This step requires a chemical handling system that can store up to 2,000 ft^3 of sodium carbonate and can feed up to 400 pounds per hour. A vendor quote was obtained for this chemical handling system (ZMI/Portec Chemical Processing Group 2005).

Estimated capital and O&M costs for the 900-gpm nitrification treatment system are presented in Appendix B–6. Estimated capital and O&M costs for the 750-gpm pumping system for delivering Colorado River water are presented in Appendix B–7.

5.3 Disposition Subsystems

5.3.1 Shallow Well Injection Into the Alluvial Aquifer

5.3.1.1 Injection of 150 gpm

It is estimated that 20 new injection wells, each delivering 7.5 gpm, will be needed to achieve a total injection rate of 150 gpm. Each new well is 6 inches in diameter and is installed to a depth of approximately 35 ft bgs using an air drilling methodology. Each is constructed of Schedule 40 PVC pipe and is screened over its lowermost 15 ft. Each well annulus is sealed with concrete and bentonite, and each well is provided with a surface pad and protective enclosure. Each well is developed and slug-tested prior to installation of appropriate valves and fittings, such that each well is capable of sustaining a 7.5-gpm injection rate. One 150-gpm pump is used to pump the treated water from the sedimentation basin into the injection system. A standby pump is maintained in the event that the main injection pump needs repair. Samples will be collected from each new injection well and analyzed for TDS, ammonia, and uranium content. Estimated capital and O&M costs for the 150-gpm injection system are presented in Appendix B–8.

5.3.1.2 Injection of 900 gpm

Under the nitrification treatment option that blends 150 gpm of extracted ground water with 750 gpm of diverted river water, it is estimated that 120 new injection wells, each delivering 7.5 gpm, will be needed to achieve the 900-gpm design injection rate. Each new well is 6 inches in diameter and will be drilled approximately 35 ft bgs using an air drilling methodology. Each well is constructed of Schedule 40 PVC pipe, the bottom 15 ft of which is screened. Each well annulus is sealed with concrete and bentonite, and each well is provided with a surface pad and protective enclosure. After construction of the wells, each well is developed and slug-tested prior to installation of associated valves and fittings, such that each well is capable of sustaining a 7.5-gpm injection rate. One 900-gpm pump is used to pump the treated water from the sedimentation basin to the injection system, and an identical standby pump is maintained. Samples are collected from each new well and analyzed for TDS, ammonia, and uranium concentrations. Estimated capital and O&M costs for the 900-gpm shallow well injection system are presented in Appendix B–9.

5.3.2 Infiltration Gallery

5.3.2.1 Infiltration of 150 gpm

An infiltration gallery provides an alternative to the shallow well injection system for returning treated water to the subsurface. The infiltration gallery design takes into account the hydraulic conductivity of the sand and gravel zone that exists approximately 15 ft bgs near the west bank of the Colorado River. An infiltration gallery, designed to accommodate 150 gpm of recharge, is 100 ft wide by 300 ft long, and has an excavated depth of 15 ft. Four-inch-diameter perforated PVC pipe is placed in the bottom of the gallery on 5-ft centers, with pipe running the full length of the infiltration gallery. The conceptual design calls for the infiltration gallery to be backfilled with excavated material upon completion of pipe installation. Estimated capital and O&M costs for the 150-gpm infiltration gallery are presented in Appendix B–10.

5.3.2.2 Infiltration of 900 gpm

The infiltration gallery designed to accommodate 900 gpm of treated effluent from a nitrification-only treatment system is approximately 230 ft wide by 680 ft long and has an excavated depth of 15 ft. Four-inch-diameter perforated PVC pipe is placed in the bottom of the gallery on 5-ft centers, with pipe running the full length of the infiltration gallery. It is assumed that the infiltration gallery is backfilled with the excavated material after the pipe has been installed. Estimated capital and O&M costs for the 900-gpm infiltration gallery are presented in Appendix B–11.

5.3.3 Percolation Systems Above the Alluvial Aquifer

5.3.3.1 Wetlands

A constructed wetlands system is designed to accommodate 2 cubic feet per second (cfs) of Colorado River water after storage and settling in the storage pond. The constructed wetlands are a seven-wetland system with each wetland constructed as follows. Each constructed wetland is 185 ft wide by 395 ft long and has an average excavated depth of 7.5 ft. Hydro-seeded topsoil will cover each wetland with a minimum topsoil depth of 6 inches. Each wetland would be constructed with an inlet, percolation, and outlet zones with a perimeter embankment. The inlet and outlet zones are constructed of 1.5- to 3-inch gravel-filled gabion baskets. Water distribution in the inlet zone and collection in the outlet zone is accomplished by using 6-inch-diameter perforated PVC pipe. The percolation zone is backfilled with ¾-inch to 1-inch gravel. Estimated capital and O&M costs for the 2 cfs wetlands are presented in Appendix B–16.

5.3.3.2 Surface Spreading Basin

A surface spreading basin designed to accommodate 2 cfs of Colorado River water after storage and settling in the storage pond has dimensions of 208 ft wide by 1,625 ft long, with a 2-ft-high berm around the perimeter of the basin. The basin will have an outlet and splash pad. Colorado River water will be distributed to the spreading basin from a 6-inch-diameter inlet pipe along the length of the basin. The spreading basin area will be cleared and rough graded to accommodate percolation. Estimated capital and O&M costs for the 2 cfs spreading basin are presented in Appendix B–17.

5.3.4 Paradox Formation Injection

The Paradox Formation is estimated to be more than 400 ft bgs in the portion of the Moab site where injection of the treated water would be conducted. There are no existing injection wells into this formation in the vicinity of the site. It is assumed that one injection well capable of injecting approximately 150 gpm would be constructed for this disposition subsystem. The new well would be 6 inches in diameter and would be drilled anywhere between 500 ft bgs and 1,000 ft bgs using mud-drilling methodology. The well is constructed from Schedule 40 PVC pipe and includes a screened interval over its lowermost 40 ft. The well annulus is sealed with concrete and bentonite, and each well is provided with a surface pad and protective enclosure. It is assumed that after construction of the well, it is developed and slug-tested prior to installation of needed valves and fittings, such that the well is capable of disposing of 150 gpm under high-pressure conditions. An identical standby injection well is constructed to pump the treated water into the Paradox Formation when the primary well is undergoing maintenance. The pump in each well is equipped with a 5-hp motor. Samples are collected from each new well and analyzed for TDS, ammonia, and uranium concentrations shortly after the well is constructed. Estimated capital and O&M costs for the 150-gpm Paradox Formation injection system are presented in Appendix B–12.

Another option for deep well injection, and one that may be necessary depending upon regulatory approval, is to construct a well into the lowermost portion of the Paradox Formation or into the underlying Leadville Limestone. The depth to the base of the Paradox Formation beneath the site is estimated at 8,000 ft bgs. The associated capital and O&M cost for this option is likely to be an order of magnitude greater than the shallower option described above.

5.4 Colorado River Pumping Systems

5.4.1 River Pumping Rate of 150 gpm

An existing settling pond that receives water pumped from the Colorado River is currently used to deliver water to pilot vegetation test plots and the Configuration 2 injection system at the Moab site. The existing settling pond will be replaced with a new river water storage pond that includes adequate capacity for 150 gpm of injection water. Under an alternative that simply delivers fresh water to a 60-well injection system, it is assumed that a 150-gpm pump will be used to pump river water from the storage pond to wells or an infiltration gallery. This pump will be equipped with a 10-hp motor. Pumped water from the settling pond will be delivered directly into a disposal system in a manner similar to the program described in Section 4.5. Estimated capital and O&M costs for the 150-gpm Colorado River pumping systems are presented in Appendix B–13.

5.4.2 River Pumping Rate of 750 gpm

Under an alternative that delivers 750 gpm of river water for mixing with 150 gpm of extracted ground water, the conceptual design calls for a system similar to that described in Section 5.4.1, except that a second new river water storage pond and larger pumps are required. Under an alternative that simply delivers fresh water to an aeration/mixing basin, it is assumed that a

750-gpm pump will be used to pump river water from the storage pond to aeration basin. This pump will be equipped with a 30-hp motor. Estimated capital and O&M costs for the storage and pumping of 750 gpm of river water are presented in Appendix B–14.

5.4.3 River Pumping Rate of 2 cfs

Under an alternative that delivers 2 cfs of river water for injection into the shallow aquifer, the conceptual design calls for a system similar to that described in Section 5.4.1, except that a second new river water storage pond and larger pumps are required. Under an alternative that simply delivers fresh water to a water injection system described in Section 4.5, it is assumed that a 900-gpm pump will be used to pump river water from the storage pond for injection. This pump will be equipped with a 40-hp motor. Estimated capital and O&M costs for the storage and pumping of 2 cfs of river water are presented in Appendix B–15.

6.0 Analysis of Full Treatment Alternatives

An alternative is defined as a combination of the subsystems described in the previous chapter to extract the ground water, manage/treat it to reduce the ammonia concentration, and dispose of the treated ground water. The following alternatives will be analyzed in greater detail in the next section.

1. Extraction of 150 gpm of ground water from wells, followed by well injection into or below the Paradox Formation.
2. Extraction of 150 gpm of ground water from wells, followed by treatment in an evaporation pond system.
3. Extraction of 150 gpm of ground water from wells, followed by treatment using ammonia stripping and ion exchange, and disposal via well injection into or below the Paradox Formation.
4. Extraction of 150 gpm of ground water from wells, followed by treatment using ammonia stripping and ion exchange, and disposal via shallow well injection into the alluvial aquifer.
5. Extraction of 150 gpm of ground water from wells, followed by treatment using ammonia stripping and ion exchange, and disposal via an infiltration gallery.
6. Extraction of 150 gpm of ground water from wells followed by treatment using ammonia stripping and nitrification, and disposal via well injection into or below the Paradox Formation.
7. Extraction of 150 gpm of ground water from wells followed by treatment using ammonia stripping and nitrification, and disposal via well injection into the alluvial aquifer.
8. Extraction of 150 gpm of ground water from wells followed by treatment using ammonia stripping and nitrification, and disposal in an infiltration gallery.

9A. Diversion of 150 gpm of Colorado River water followed by well injection into the alluvial aquifer.

9B. Diversion of 150 gpm of Colorado River water followed by infiltration gallery injection into the alluvial aquifer.

10. Extraction of 150 gpm of ground water from wells for blending with 750 gpm of Colorado River water, and followed by nitrification treatment and shallow well injection into the alluvial aquifer.

11. Extraction of 150 gpm of ground water from wells, blended with 750 gpm of Colorado River water, and followed by nitrification treatment and disposal in an infiltration gallery.

12A. Diversion of 2 cfs of Colorado River water followed by wetlands percolation into the alluvial aquifer.

12B. Diversion of 2 cfs of Colorado River water followed by spreading basin percolation into the alluvial aquifer.

6.1 Extraction of 150 gpm of ground water from wells followed by well injection into or below the Paradox Formation

This alternative combines extraction wells described in Section 5.1 with direct injection of the extracted water into or below the Paradox Formation described in Section 5.3.3. As shown in Appendix A, the capital cost for this alternative, when installation is into the upper portion of the Paradox Formation, is approximately $800,000. It is assumed that the labor of two FTEs is adequate to operate and maintain both the extraction and injection wells, resulting in a total O&M cost of $146,000 per year. The O&M safety issues associated with this alternative include the typical risks stemming from use of electricity and maintenance of pumps and piping systems. In general, this alternative has a low safety risk with few hazards. Additional injection testing may be necessary to establish the design rate for injection.

Figure 6–1 depicts the anticipated locations of injection and extraction wells into or below the Paradox Formation. If it is necessary to install the injection well near the base of or below the Paradox Formation at depths of approximately 8,000 ft, the cost will be much greater. Capital costs are estimated between $3 and 5 million, and O&M costs will be nearly an order of magnitude greater than the shallower well option. Safety risks also will be slightly higher due to increase pressures associated with injection to these much greater depths. Additional testing will be necessary to establish the design rate for injection.

Neither option under this alternative meets the ground water remediation objective of treating the extracted ground water to an ammonia concentration less than 3 mg/L. However, this alternative does remove contaminant mass from the ground water and disposes of it in or below the Paradox Formation, far from sites of natural ground water discharge.

6.2 150 gpm of ground water from extraction wells followed by treatment in an evaporation pond system

This alternative combines extraction wells described in Section 5.1 with the evaporation pond treatment subsystem described in Section 5.2.1. The extraction wells, described in Section 5.1.1, are connected to the evaporation system using 4-inch-diameter Schedule 40 PVC pipe such that the wells can discharge the ground water into both of the two ponds at any given time. Each evaporation pond is equipped with a spray-enhanced recirculation system consisting of two 750-gpm centrifugal pumps powered by a 30-hp motor; one pump in each pair is a standby unit. The pumps are connected to a recirculation header located along the perimeter of each pond. Two-inch-diameter spray bars are connected to the 6-inch-diameter header.

Figure 6–2 depicts the location of the evaporation pond system and extraction wells. The extraction wells are in the same locations discussed in Section 5.1.1. The two main evaporation ponds are located north of the tailings pile, and an alternative or standby pond is located south of the existing well field. Estimated capital cost for this alternative is about $6,819,000. The costs of liners for the ponds are based on vendor quotes and installation costs for Cell 2 of the Idaho CERCLA Disposal Facility (Cook 2005, Taylor 2005).

The total O&M cost is estimated at $216,000 per year. It is assumed that three FTEs will operate and maintain both the extraction wells and the evaporation ponds. The O&M safety issues for this alternative include the typical risks associated with use of electricity, maintenance of pumps and piping systems, and open-water hazards in the evaporation ponds. It is estimated that this alternative has a low safety risk with few hazards.

This alternative does not meet the remediation objective of an ammonia concentration of 3 mg/L or less, though it does remove large amounts of contaminant mass from the subsurface. Any ground water that is not intercepted by the extraction system is expected to discharge to non-backwater portions of the Colorado River. Ground water modeling may be needed to determine the exact number and location of extraction wells required to achieve adequate control of ammonia in ground water that currently discharges to the near-shore areas of the Colorado River.

6.3 Extraction of 150 gpm of ground water from extraction wells followed by treatment using ammonia stripping and ion exchange, and disposal via well injection into or below the Paradox Formation

This alternative combines extraction wells described in Section 5.1 with the ammonia stripping system described in Section 5.2.2, the ion exchange system described in 5.2.3, and effluent injection into or below the Paradox Formation described in Section 5.3.3.

Figure 6–3 depicts the suggested location of extraction wells, the locations and spatial requirements for the ammonia stripping and ion exchange equipment, and the suggested site for effluent injection into or below the Paradox Formation. This treatment alternative does achieve the remediation goal of an ammonia concentration of less than 3 mg/L. Estimated capital cost for this alternative is $5,677,000, if the injection well is only into the upper portion of the Paradox Formation. Should it be necessary to install the injection well near the base of or below the Paradox Formation, at depths of 8,000 ft, the capital cost will increase by another $3,000,000 to $5,000,000.

With the increased complexity of treatment equipment associated with this alternative, it is anticipated that personnel will be needed at all times to operate the system. Accordingly, the number of O&M personnel required for this alternative is estimated to be 9 FTEs. Energy, chemical consumption, and O&M labor estimates indicate that the annual O&M cost is approximately $1,284,000 and will be over $2,000,000 if the deeper well option is required. The O&M safety issues under this alternative include those typically associated with use of electricity, maintenance of pumps and piping systems, and chemical handling due to pH adjustments for air stripper and ion exchange processes. This alternative has a medium safety risk, and several potential hazards will have to be addressed in O&M procedures. Pilot treatability studies will be required for both air stripping and ion exchange processes. Additional testing will be required to determine the design rate for injection, especially if the deeper well option is required.

6.4 Extraction of 150 gpm of ground water from wells followed by treatment using ammonia stripping and ion exchange, and disposal via shallow well injection into the alluvial aquifer

This alternative combines extraction wells described in Section 5.1 with the ammonia stripping system described in Section 5.2.2, the ion exchange system described in Section 5.2.3, and the shallow well injection into the alluvial aquifer described in Section 5.3.1. This treatment alternative differs from the previous one (Section 6.3) because of its use of shallow well injection in place of deep well injection into the Paradox Formation or the even deeper Leadville Limestone.

Figure 6–4 shows the locations of extraction wells and the 20 shallow injection wells, as well as the locations and spatial requirements for the ammonia stripping and ion exchange equipment. This treatment alternative does achieve the remediation goal of an ammonia concentration less than 3 mg/L. Estimated capital costs for this alternative are $6,012,000. With the increased complexity of treatment equipment used with this alternative, the number of O&M personnel needed is estimated at 9 FTEs. The combination of estimated energy and chemical consumption requirements and O&M labor results in an estimated O&M cost of approximately $1,284,000 per year. Safety issues for this alternative include the typical risks associated with the use of electricity, maintenance of pumps and piping systems, and the additional risks due to chemical handling for pH adjustments prior to air stripper and ion exchange processes. This alternative constitutes a medium safety risk, and several potential hazards will need to be addressed in O&M procedures. Pilot treatability studies will be required for both air stripping and ion exchange processes.

6.5 Extraction of 150 gpm of ground water from wells followed by treatment using ammonia stripping and ion exchange, and disposal via an infiltration gallery

This alternative combines extraction wells described in Section 5.1 with the ammonia stripping system described in Section 5.2.2, the ion exchange described in Section 5.2.3, and the infiltration gallery described in Section 5.3.2. This treatment alternative is identical to those described in sections 6.3 and 6.4, except that an infiltration gallery is used for effluent disposal.

Figure 6–5 shows the locations of the extraction wells and infiltration gallery, as well as the locations and spatial requirements for the ammonia stripping and ion exchange equipment. This treatment alternative will achieve the remediation goal of an ammonia concentration less than 3 mg/L. Estimated capital costs for this alternative are $5,924,000. As discussed in Sections 6.3 and 6.4, the number of O&M personnel required for this alternative is estimated at 9 FTEs. Estimated energy and chemical consumption and O&M labor are expected to cost approximately $1,284,000 per year. Safety issues under this alternative include the typical risks associated with the use of electricity, maintenance of pumps and piping systems, and additional risks stemming from chemical handling for pH adjustments prior to air stripper and ion exchange processes. This alternative has a medium safety risk, and several potential hazards will need to be addressed in O&M procedures. Pilot treatability studies will be required for both the air stripping and ion exchange treatment system design.

6.6 Extraction of 150 gpm of ground water from wells followed by treatment using ammonia stripping and nitrification, and disposal via well injection into or below the Paradox Formation

This alternative combines extraction wells described in Section 5.1 with the ammonia stripping system described in Section 5.2.2, the nitrification described in Section 5.2.4, and the Paradox Formation injection well described in Section 5.3.3.

Figure 6–6 depicts the locations and spatial requirements for the ammonia stripping and nitrification treatment equipment and the location of the well used for effluent injection into or below the Paradox Formation. This treatment alternative will achieve the remediation goal of an ammonia concentration less than 3 mg/L. Estimated capital cost for this alternative is $5,189,000, if injection is into the upper portion of the Paradox Formation. Should it be necessary to install the injection well near the base of or below the Paradox Formation, at depths of 8,000 ft, the capital cost will increase by another $3,000,000 to $5,000,000.

The complexity of combined ammonia stripping and nitrification is projected to require full-time O&M oversight with approximately 8 FTEs. Estimated energy and chemical consumption and O&M labor are expected to cost approximately $1,209,000 per year, and will be over $2,000,000 if the deeper well option is required. The O&M safety issues for this alternative include the typical risks associated with the use of electricity, maintenance of pumps and piping systems, and additional risks attributed to chemical handling for pH adjustments of influent water, air stripping, and nitrification processes. It is estimated that this alternative has a low to medium safety risk. Several potential hazards will need to be addressed in O&M procedures. Pilot treatability studies will be required for both the air stripping and nitrification treatment systems. Additional testing will be required to determine the design rate for injection, especially if the deeper well option is required.

6.7 Extraction of 150 gpm of ground water from wells followed by treatment using ammonia stripping and nitrification, and disposal via shallow well injection into the alluvial aquifer

This alternative combines extraction wells described in Section 5.1 with the ammonia stripping system described in Section 5.2.2, the nitrification described in Section 5.2.4, and the shallow well injection system described in Section 5.3.1. This treatment alternative is identical to the alternative presented in Section 6.6, except that treatment of effluent will be accomplished using shallow well injection into the alluvial aquifer.

Figure 6–7 depicts the locations and spatial requirements for the ammonia stripping and nitrification treatment equipment, as well as the location of proposed shallow wells for effluent injection. This treatment alternative achieves the remediation goal of an ammonia concentration less than 3 mg/L, and has an estimated capital cost of $5,524,000. As with the previous alternative, O&M for this alternative will require 8 FTEs. Estimated energy and chemical consumption and O&M labor are expected to cost approximately $1,182,000 per year. Again, safety issues include the typical risks associated with use of electricity, pump and piping maintenance, and chemical handling due to pH adjustments for air stripper and nitrification processes. Safety risk is estimated at low to medium, and several potential hazards should be addressed in O&M procedures. Pilot treatability studies will be required for both the air stripping and nitrification treatment systems.

6.8 Extraction of 150 gpm of ground water from wells followed by treatment using ammonia stripping and nitrification, and disposal into an infiltration gallery

This alternative combines extraction wells described in Section 5.1 with the ammonia stripping system described in Section 5.2.2, the nitrification system described in Section 5.2.4, and effluent injection via the infiltration gallery described in Section 5.3.2. This treatment alternative differs from the two previous ones (Sections 6.6 and 6.7) only in that the infiltration gallery is used for effluent disposal.

Figure 6–8 depicts the locations and spatial requirements for the ammonia stripping and nitrification treatment equipment and the location of the infiltration gallery. This treatment alternative achieves the remediation goal of an ammonia concentration less than 3 mg/L, and has an estimated capital cost of $5,189,000. As with the previous alternative, O&M for this alternative will require 8 FTEs. Estimated energy and chemical consumption and O&M labor are expected to cost approximately $1,209,000 per year. Again, safety issues include the typical risks associated with use of electricity, pump and piping maintenance, and chemical handling due to pH adjustments for air stripper and nitrification processes. This alternative has a low to medium safety risk, and several potential hazards will need to be addressed in O&M procedures. Pilot treatability studies will be required for both the air stripping and nitrification treatment systems.

6.9 Diversion of 150 gpm of Colorado River Water

A. Diversion of 150 gpm of Colorado River water for well injection into the alluvial aquifer

This alternative combines diversion of Colorado River water described in Section 5.4.1 with the shallow well injection into the alluvial aquifer described in Section 5.3.1.1. Under this alternative, surface water is diverted from the Colorado River at an average rate of 150 gpm into a new river water storage pond for settlement. From this pond it is then injected into the alluvial aquifer at this average rate. The settling pond volume is designed to be adequate for the storage of this additional volume of Colorado River water. Two 10-hp centrifugal pumps are used to pump water from the river, one being used in standby mode. Approximately 2,000 ft of 2-inch-diameter Schedule 40 PVC pipe is used to pipe the water to the settling pond and to the shallow well injection system, as depicted on Figure 6–9.

It is not clear whether this treatment alternative has the capacity to achieve the remediation goal of an ammonia concentration less than 3 mg/L in ground water, but it does appear capable of reducing ammonia concentrations in the river to acceptable levels (DOE 2005c). Additional river characterization and ground water modeling are needed to assess the effectiveness of this treatment alternative and to determine the location of injection wells. The capital cost for this alternative is $463,000. The number of O&M personnel needed to operate and maintain this alternative is estimated to be 2 FTEs. Energy consumption plus the O&M labor results in an estimated annual O&M cost of $136,000. The O&M safety issues for this alternative include the typical risks associated with use of electricity, maintenance of pump and piping systems, and any potential hazards associated with the open water in settling ponds. This alternative constitutes a relatively low safety risk.

B. Diversion of 150 gpm of Colorado River water followed by infiltration gallery injection into the alluvial aquifer

This alternative combines diversion of Colorado River water described in Section 5.4.1 with the infiltration gallery injection into the alluvial aquifer described in Section 5.3.2.1. Under this alternative, surface water is diverted from the Colorado River at an average rate of 150 gpm into a settling pond. From the pond it is then injected into the alluvial aquifer at this average rate. The settling pond's volume is designed to be adequate for the storage of this additional volume of Colorado River water. Two 10-hp centrifugal pumps are used to pump water from the river, one being used in standby mode. Approximately 2,000 ft of 2-inch-diameter Schedule 40 PVC pipe is used to pipe the water to the settling pond and to the infiltration gallery injection system, as depicted on Figure 6–10.

It is not clear whether this treatment alternative has the capacity to achieve the remediation goal of an ammonia concentration less than 3 mg/L in ground water, but it does appear capable of reducing ammonia concentrations in the river to acceptable levels (DOE 2005c). Additional river characterization and ground water modeling are needed to assess the effectiveness of this treatment alternative and to determine the location of the infiltration gallery. The capital cost for this alternative is $121,000. The number of O&M personnel needed to operate and maintain this alternative is estimated to be 2 FTEs. Energy consumption plus the O&M labor results in an estimated annual O&M cost of $136,000. The O&M safety issues for this alternative include the typical risks associated with use of electricity, maintenance of pump and piping systems, and any potential hazards associated with the open water in settling ponds. This alternative constitutes a relatively low safety risk.

6.10 Extraction of 150 gpm of ground water from wells for blending with 750 gpm of Colorado River water followed by nitrification treatment and shallow well injection into the alluvial aquifer

To reduce ammonia concentrations of influent to a nitrification system to 150 mg/L or less (EPA 1993), this alternative calls for the prior blending of 750 gpm of Colorado River water with 150 gpm of ground water. The proposed treatment in this alternative combines extraction wells described in Section 5.1, Colorado River diversion described in Section 5.4.2, nitrification processes described in Section 5.2.4.1, and the shallow well injection into the alluvial aquifer described in Section 5.3.1. The conceptual design for the 900-gpm nitrification system follows the same principles and methods invoked for the 150-gpm nitrification system. The nitrification treatment process makes use of an aeration basin and a sedimentation basin. The aeration basin is square (95 ft per side) and contains eight 30-hp surface aerators. The aeration basin is approximately 12 ft deep, which allows for 2 ft of freeboard above 10 ft of water. A 10-ft-wide embankment with a side slope of 3:1 forms the perimeter of the aeration basin to allow access for O&M activities.

The sedimentation basin is also square (265 ft per side), has 3:1 side slopes, and is approximately 12 ft deep. A 5-ft-deep solids storage zone occupies the bottom of the basin and solids removal is required once every 10 years. An overlying 5-ft-thick settling zone is overlain by 2 ft of freeboard.

Alkalinity levels necessary for carrying out the nitrification treatment are sustained through the addition of sodium carbonate. This requires a chemical handling system that can store up to 2,000 ft^3 of sodium carbonate and can feed as much as 400 pounds per hour into the aeration basin. A vendor quote was obtained for the purpose of estimating the cost of a chemical handling system (ZMI/Portec Chemical processing Group 2005). The river pumping system uses 30-hp centrifugal pumps, each capable of delivering 750 gpm. Figure 6–11 depicts the locations and spatial requirements for the nitrification treatment system as well as the locations of wells. This treatment alternative achieves the remediation goal of an ammonia concentration in ground water of less than 3 mg/L.

The shallow well injection system under this alternative is quite large (Figure 6-11) and requires 120 wells to deliver a total of 900 gpm of treated water. The new injection wells would be constructed in the same manner as described in Section 5.3.1.

The estimated capital cost for this alternative is $4,126,000. The number of O&M personnel required to operate the river diversion, nitrification treatment, and shallow well injection systems is estimated at 2 FTEs. The estimated annual O&M cost of approximately $692,000 takes into account energy consumption, chemical needs, and O&M labor. Safety issues associated with this alternative include the typical risks associated with use of electricity, pump and piping maintenance, and chemical handling in support of the nitrification treatment. The safety risk of this alternative is categorized as low; several potential hazards will need to be addressed in O&M procedures. Pilot treatability studies will be required prior to the final design of the nitrification treatment system.

6.11 Extraction of 150 gpm of ground water for blending with 750 gpm of Colorado River water, followed by nitrification treatment and disposal in an infiltration gallery

This alternative calls for the blending of 750 gpm of Colorado River water with 150 gpm of extracted ground water prior to delivering influent to the nitrification system described in Section 5.4.2. Effluent disposal is accomplished by using the infiltration gallery described in Section 5.3.2.2. Figure 6–12 shows the locations and the spatial requirements for the two earthen basins (aeration and sedimentation) required for nitrification treatment, as well the location of the infiltration gallery. This treatment alternative achieves the remediation goal of an ammonia concentration less than 3 mg/L. As described in Section 5.4.2, diversion of river water is carried out by a 30-hp centrifugal pump. The infiltration gallery system, designed to facilitate infiltration of 900 gpm of treated water is approximately 230 ft wide by 680 ft long. Perforated 4-inch-diameter Schedule 40 PVC pipe is laid along the bottom of the gallery on 5-ft centers (Section 5.3.2.2).

The estimated capital cost of this alternative is $2,029,000. Two FTEs comprise the O&M personnel that are required for this alternative. Estimated energy and chemical consumption plus the O&M labor results in an estimated O&M cost of $692,000 per year. Safety issues for this alternative include the typical risks associated with use of electricity, maintenance of pump and piping systems, and any additional chemical handling risks associated with nitrification treatment. This alternative has a low safety risk, and several potential hazards must be addressed in O&M procedures. Pilot treatability studies of the nitrification processes will be required.

6.12 Diversion of 2 cfs of Colorado River water

A. Diversion of 2 cfs of Colorado River water followed by wetlands percolation into the alluvial aquifer

This alternative combines diversion of Colorado River water described in Section 5.4 with the wetlands percolation into the alluvial aquifer described in Section 5.3.3.1. Under this alternative, surface water is diverted from the Colorado River at an average rate of 2 cfs into a new settling pond. From this pond it is then percolated into the alluvial aquifer at this average rate. The settling pond volume is designed to be identical to the river water storage pond to adequately store and allow sediment settling for this additional volume of Colorado River water. Two 40-hp centrifugal pumps are used to pump water from the storage pond, one being used in standby mode. Approximately 3,500 ft of 6-inch-diameter Schedule 40 PVC pipe is used to transfer the water from the settling pond and to the wetlands system, as depicted on Figure 6–13.

It is not clear whether this treatment alternative has the capacity to achieve the remediation goal of an ammonia concentration less than 3 mg/L in ground water, but it does appear capable of reducing ammonia concentrations in the river to acceptable levels (DOE 2005c). Additional river characterization and ground water modeling are needed to assess the effectiveness of this treatment alternative.

The capital cost for this alternative is $6,200,000. The number of O&M personnel needed to operate and maintain this alternative is estimated to be 2 FTEs. Energy consumption plus the O&M labor results in an estimated annual O&M cost of $151,000. The O&M safety issues for this alternative include the typical risks associated with use of electricity, maintenance of pump and piping systems, and any potential hazards associated with the open water in settling ponds. This alternative constitutes a relatively low safety risk.

B. Diversion of 2 cfs of Colorado River water followed by spreading basin percolation into the alluvial aquifer

This alternative combines diversion of Colorado River water described in Section 5.4 with the spreading basin percolation into the alluvial aquifer described in Section 5.3.3.2. Under this alternative, surface water is diverted from the Colorado River at an average rate of 2 cfs into a new settling pond. From this pond it is then transferred to the spreading basin for percolation into the alluvial aquifer at this average rate. The settling pond volume is designed to be identical to the river water storage pond to adequately store and allow sediment settling for this additional volume of Colorado River water. Two 40-hp centrifugal pumps are used to pump water from the river, one being used in standby mode. Approximately 3,500 ft of 6-inch-diameter Schedule 40 PVC pipe is used to pipe the water from the settling pond and to the spreading basin, which is depicted on Figure 6–14.

It is not clear whether this treatment alternative has the capacity to achieve the remediation goal of an ammonia concentration less than 3 mg/L in ground water, but it does appear capable of reducing ammonia concentrations in the river to acceptable levels (DOE 2005c). Additional river characterization and ground water modeling are needed to assess the effectiveness of this treatment alternative.

The capital cost for this alternative is $411,000. The number of O&M personnel needed to operate and maintain this alternative is estimated to be 2 FTEs. Energy consumption plus the O&M labor results in an estimated annual O&M cost of $151,000. The O&M safety issues for this alternative include the typical risks associated with use of electricity, maintenance of pump and piping systems, and any potential hazards associated with the open water in settling ponds. This alternative constitutes a relatively low safety risk.

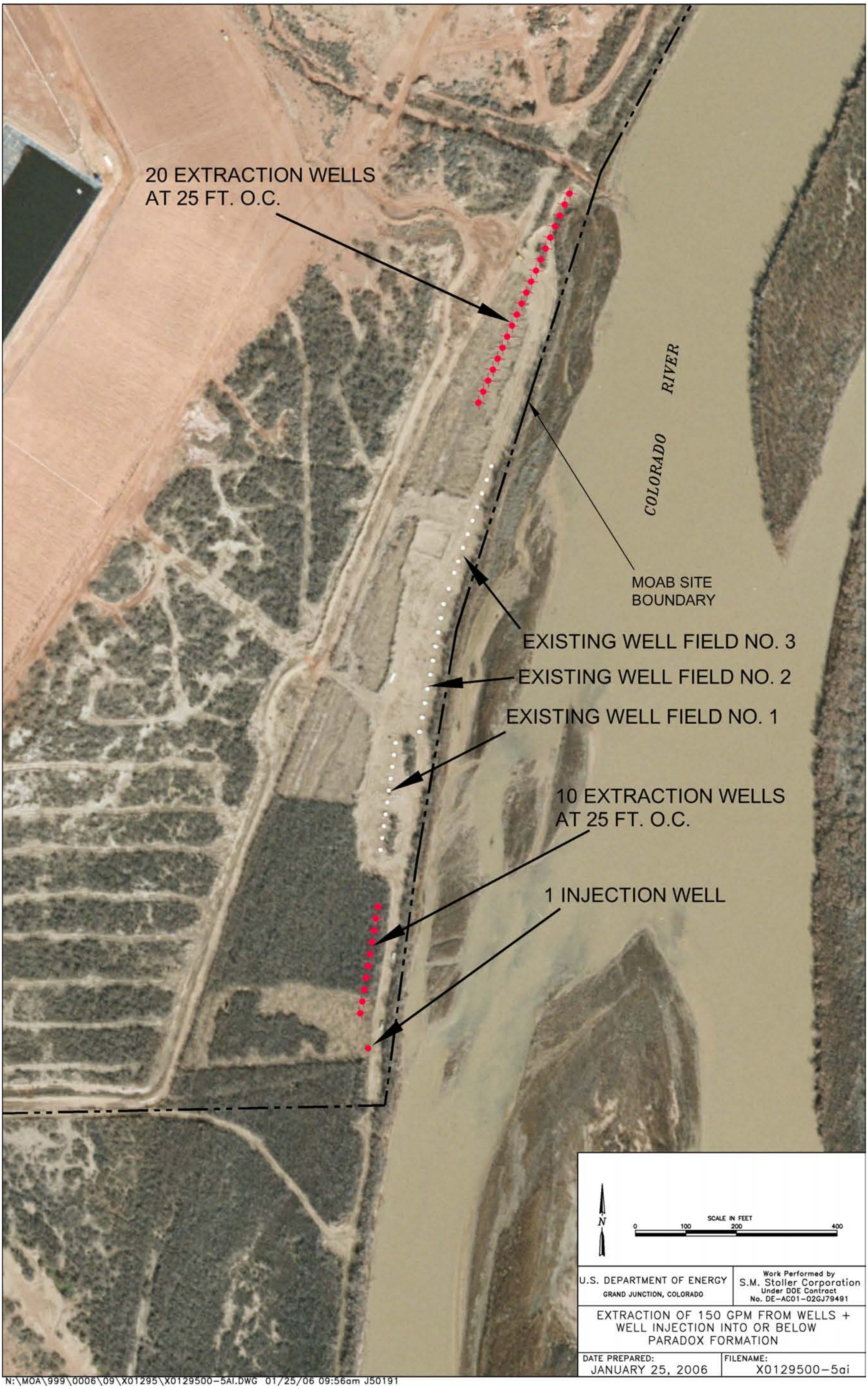

Figure 6-1. Alternative No. 1

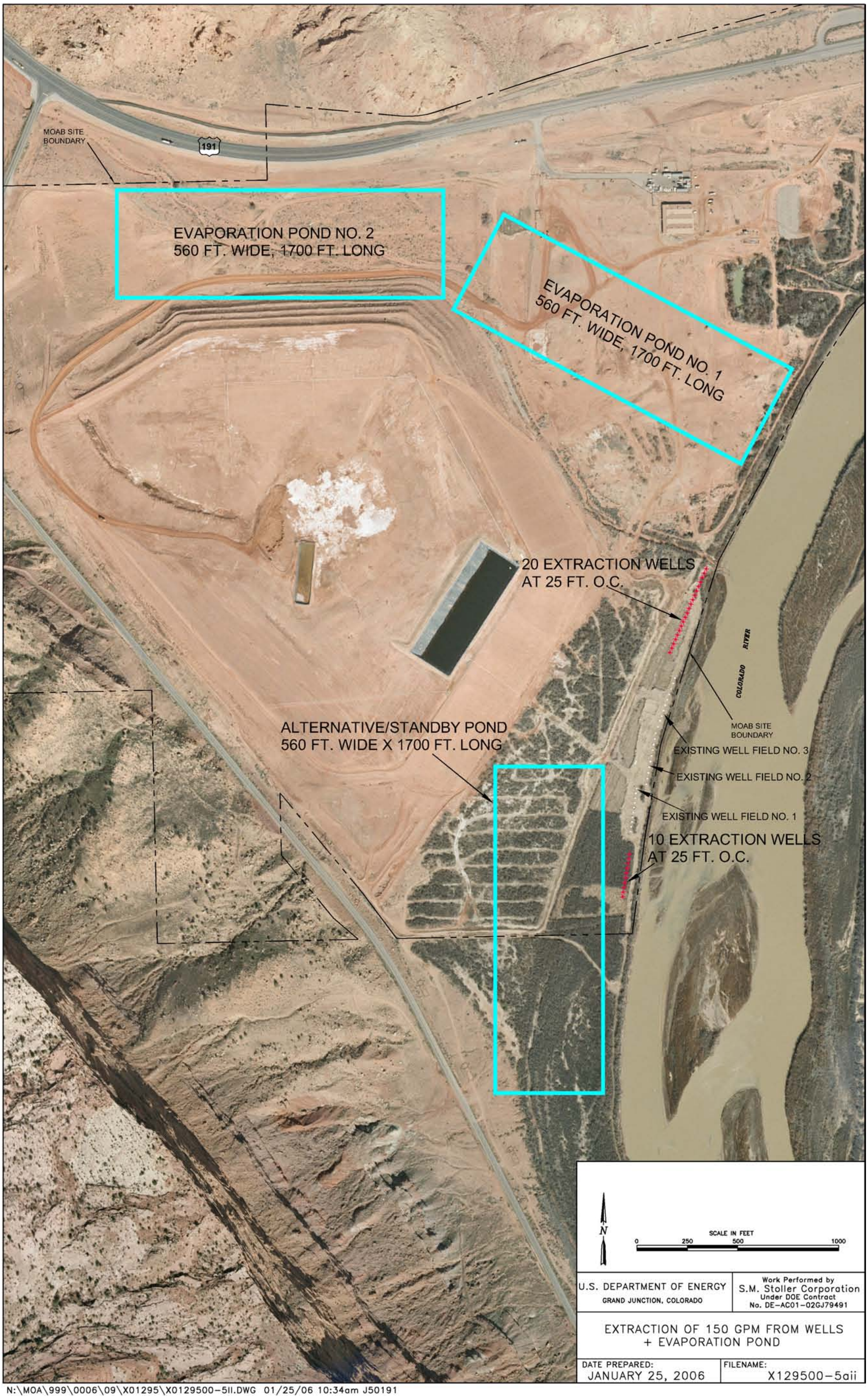

Figure 6-2. Alternative No. 2

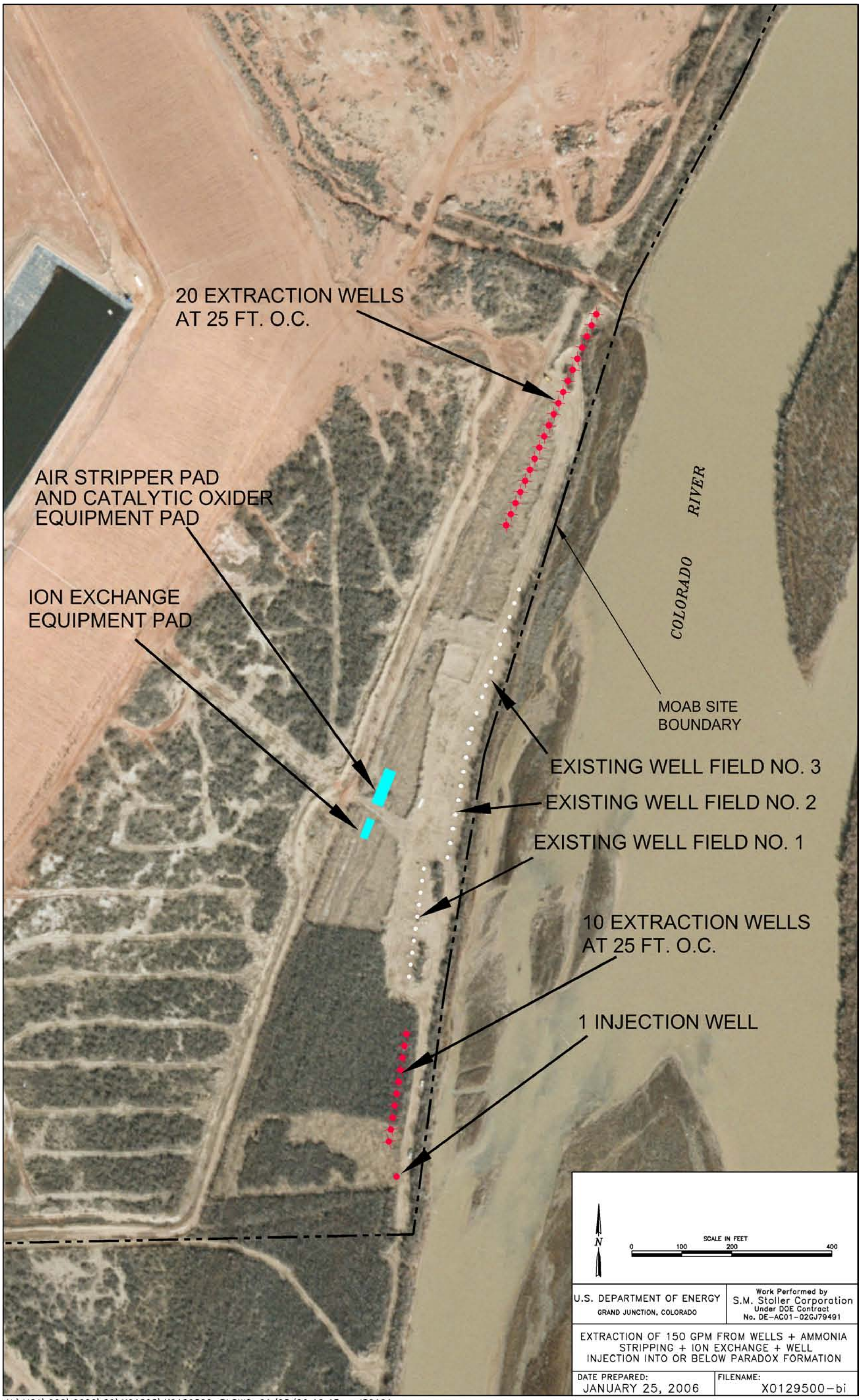

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Figure 6-3. Alternative No. 3

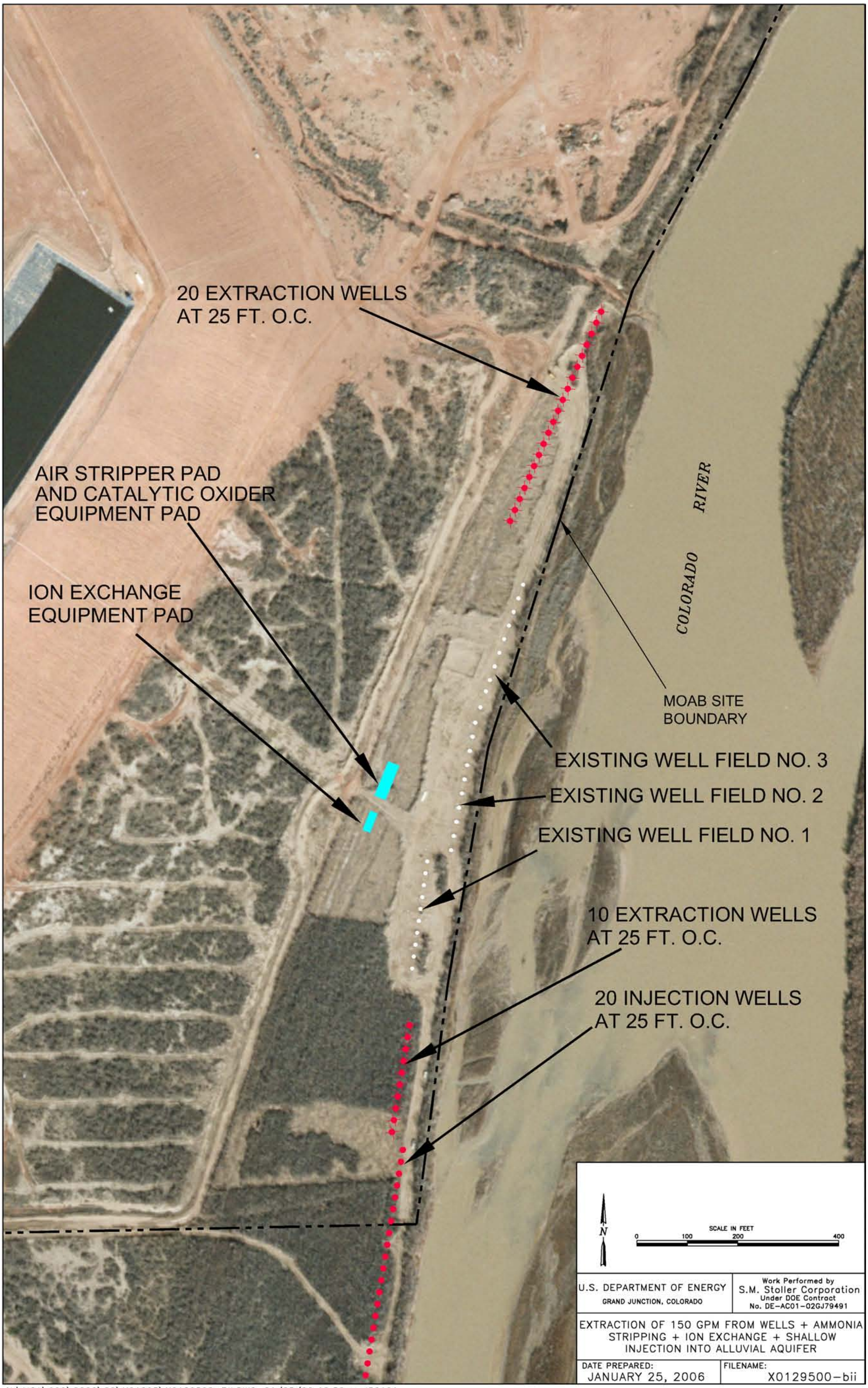

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Figure 6-4. Alternative No. 4

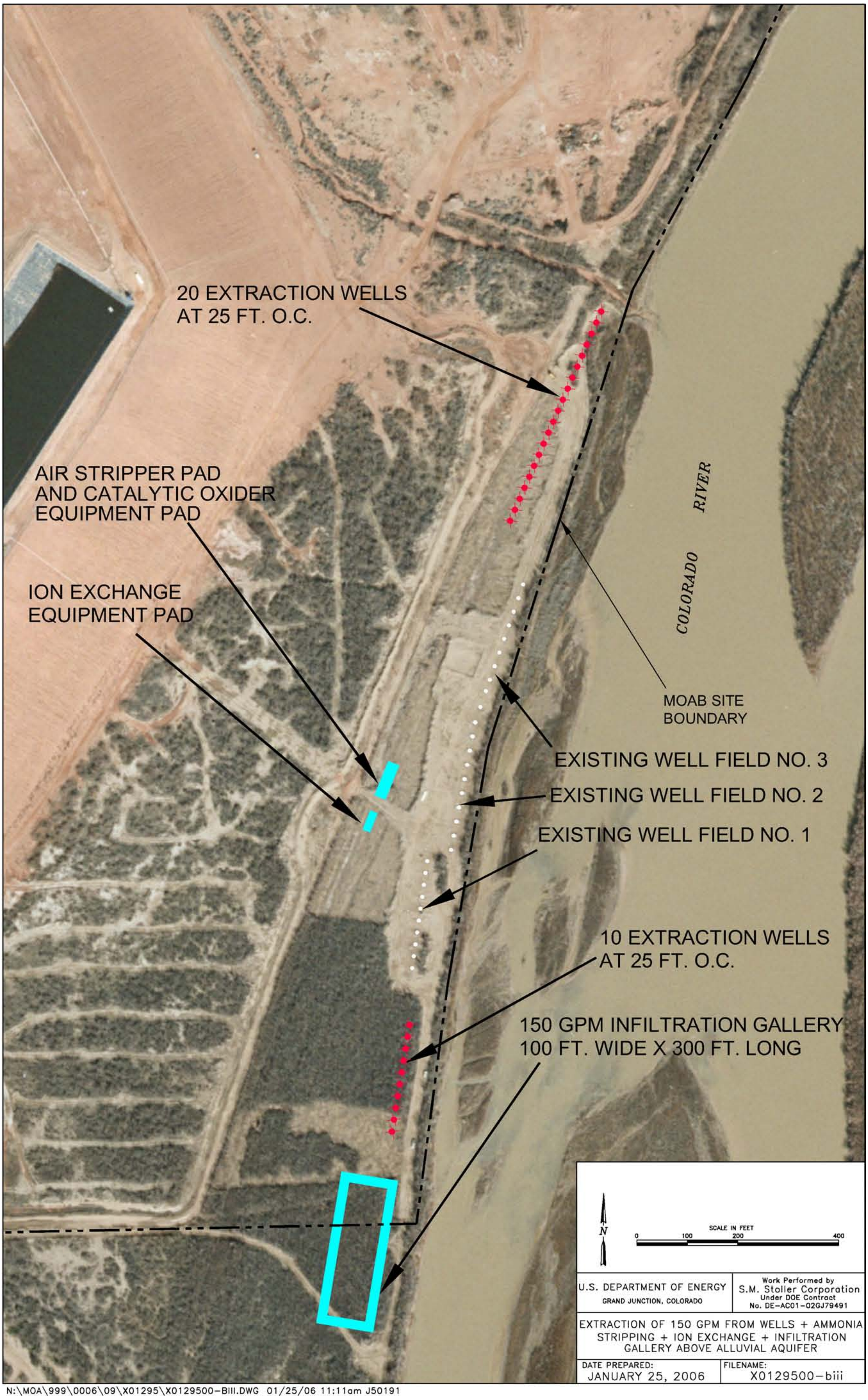

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Figure 6-5. Alternative No. 5

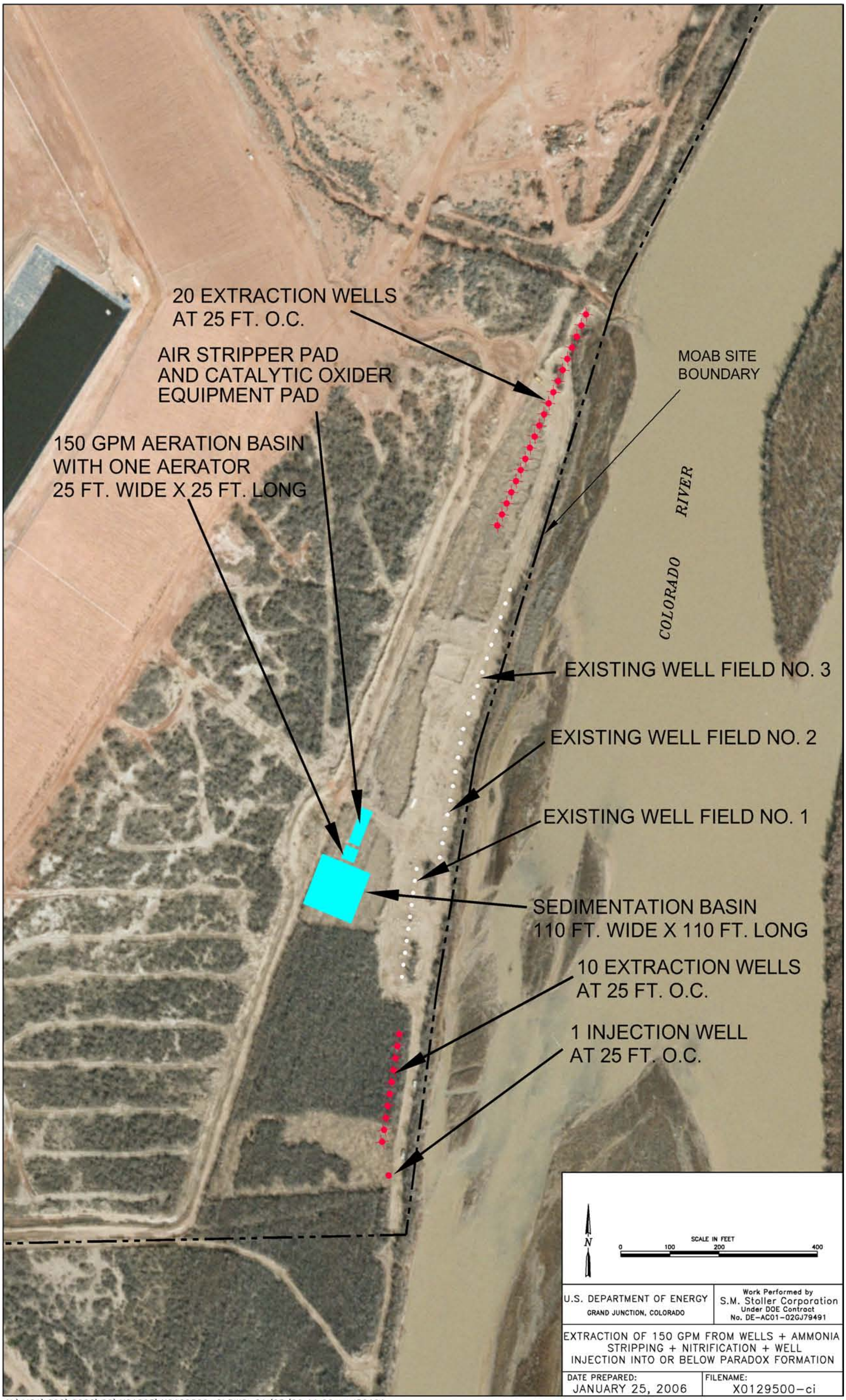

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Figure 6-6. Alternative No. 6

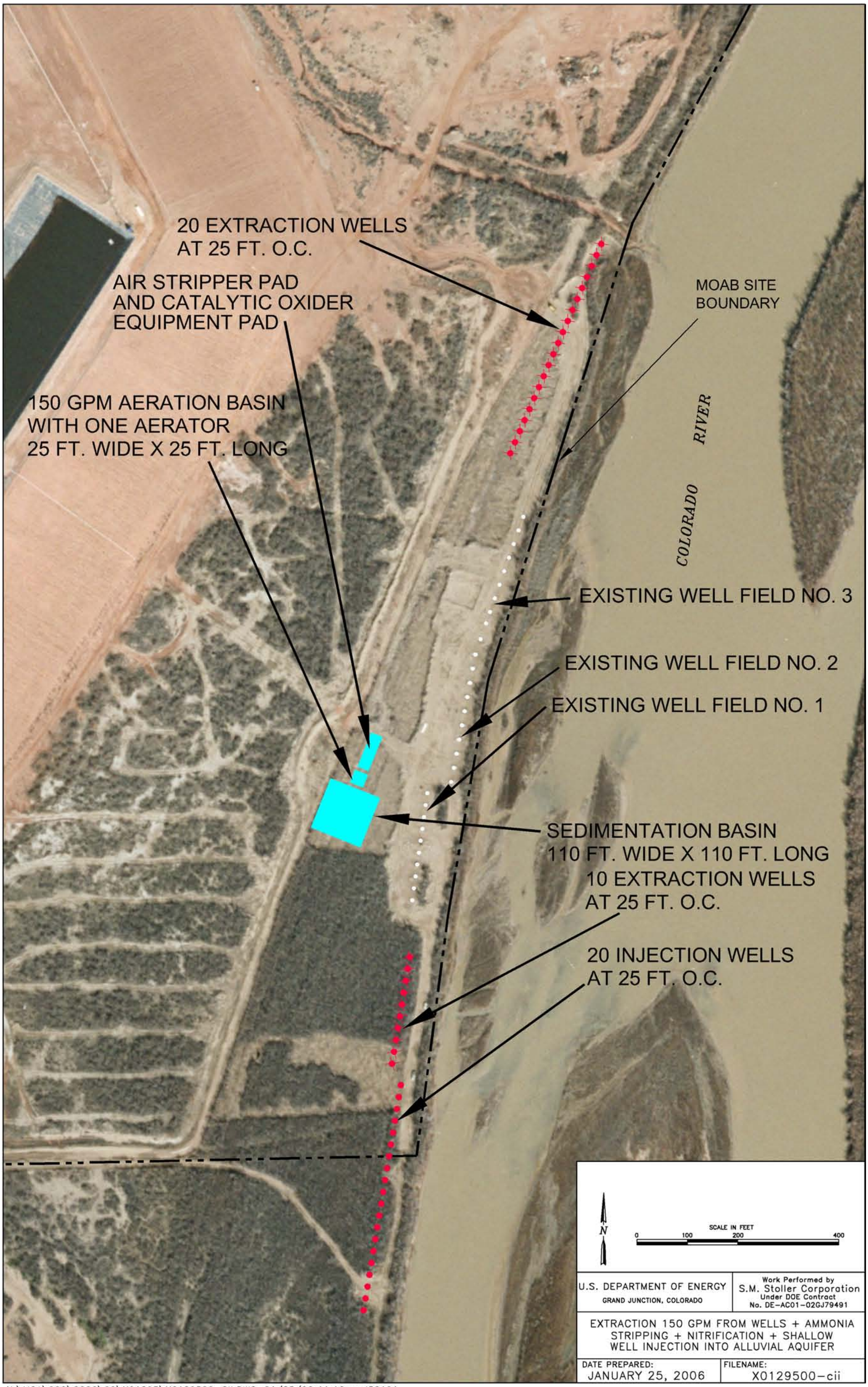

Figure 6-7. Alternative No. 7

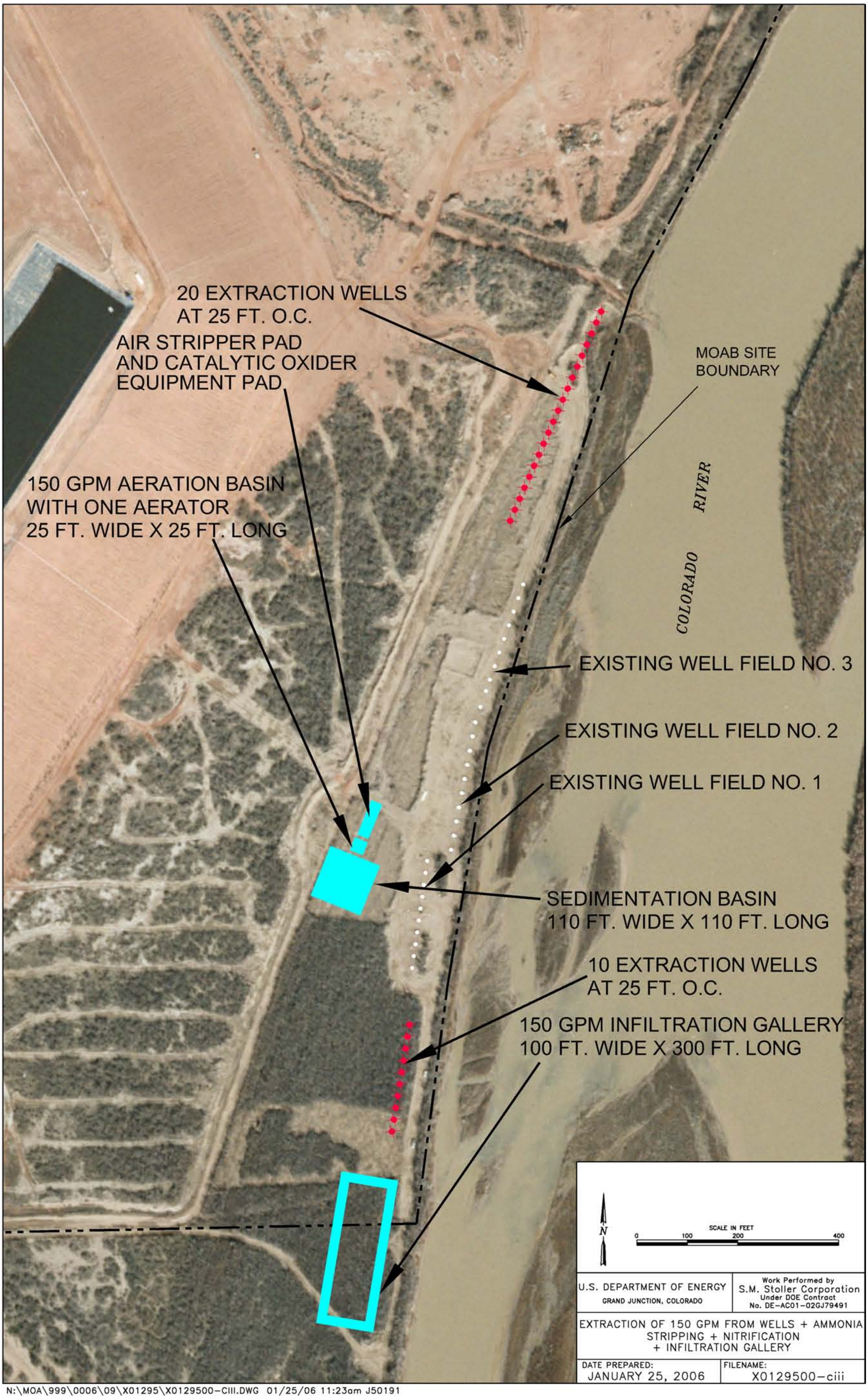

Figure 6-8. Alternative No. 8

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Figure 6-9. Alternative No. 9A

Figure 6-10. Alternative No. 9B

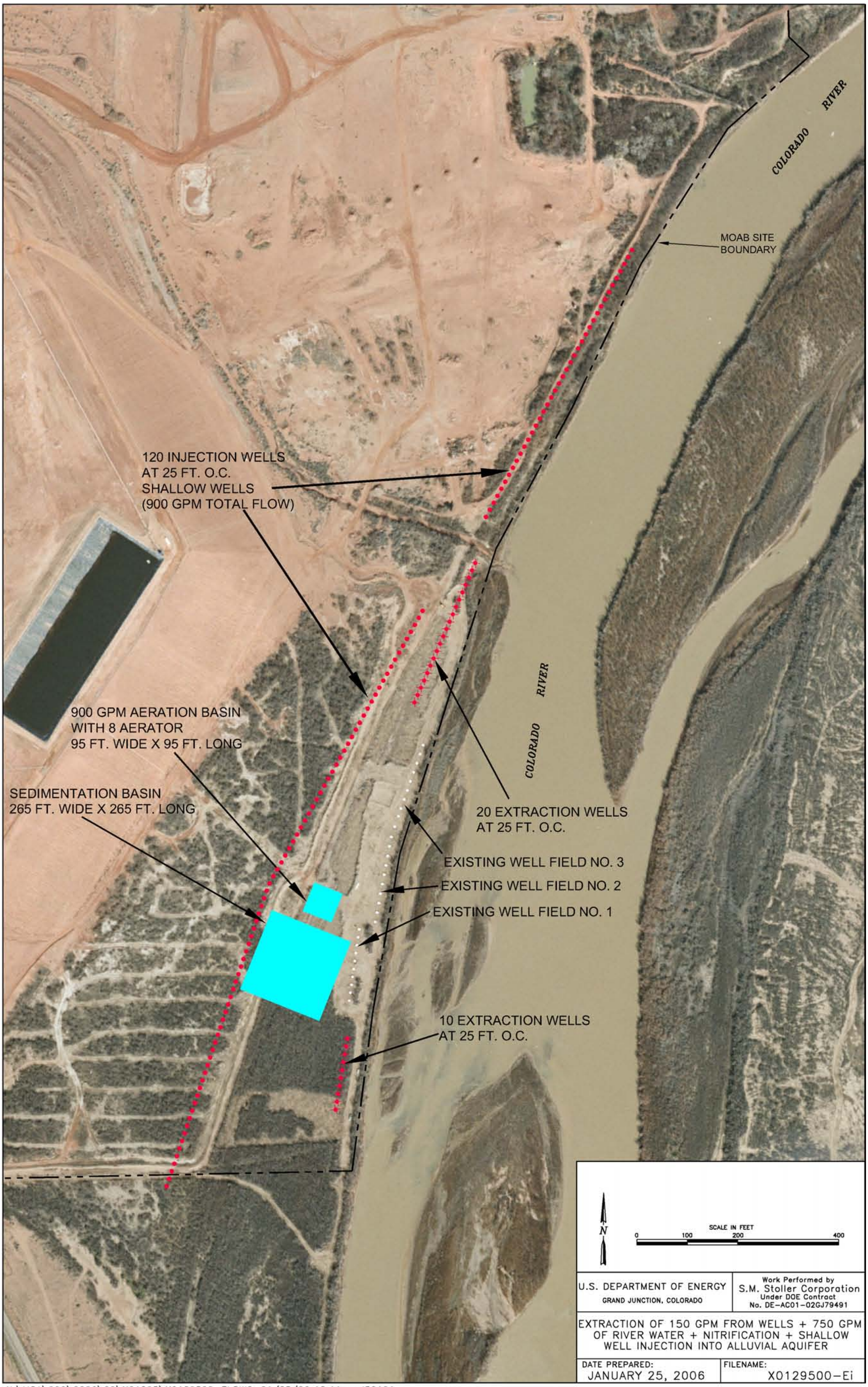

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Figure 6-11. Alternative No. 10

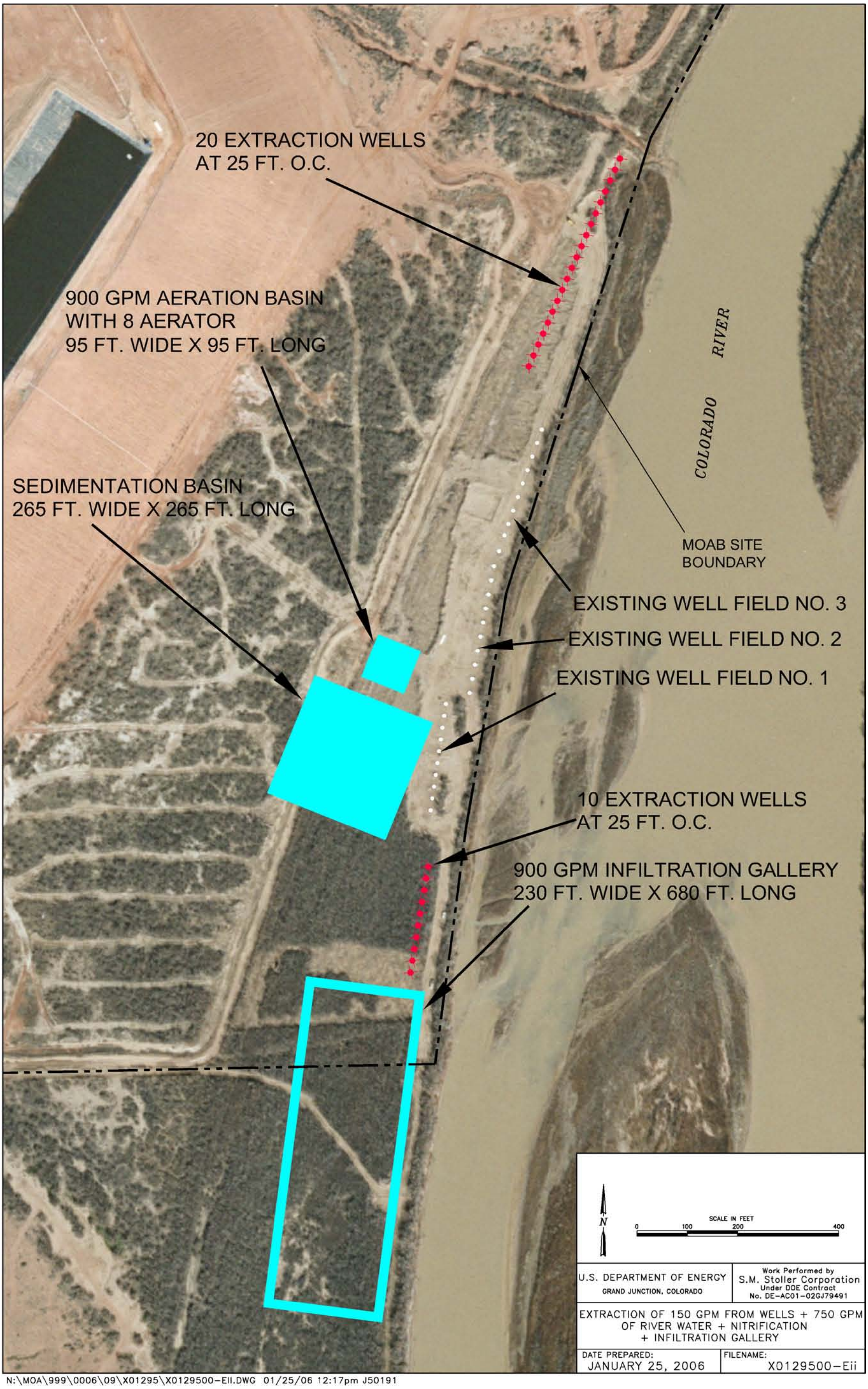

Figure 6-12. Alternative No. 11

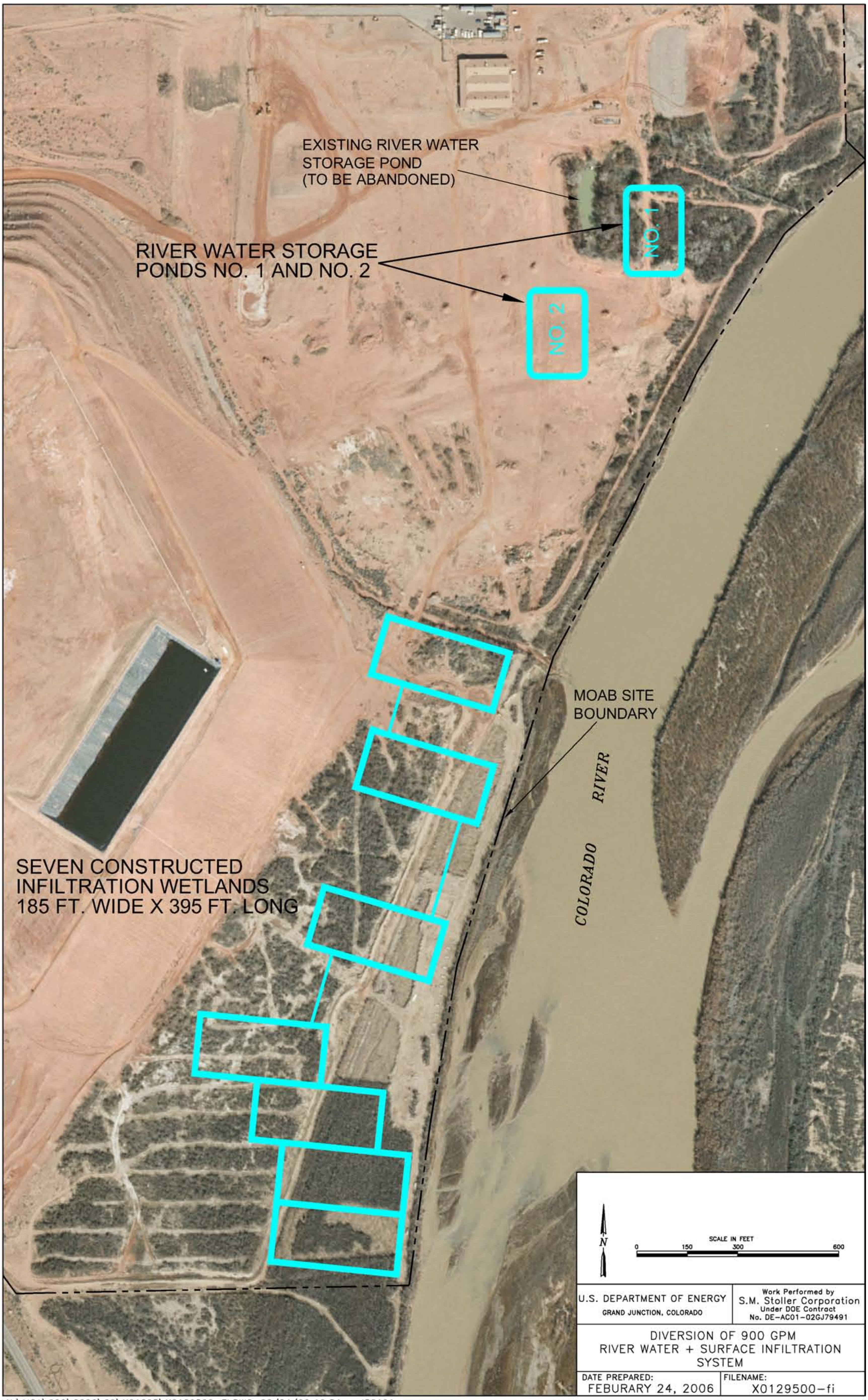

Figure 6-13. Alternative No. 12A

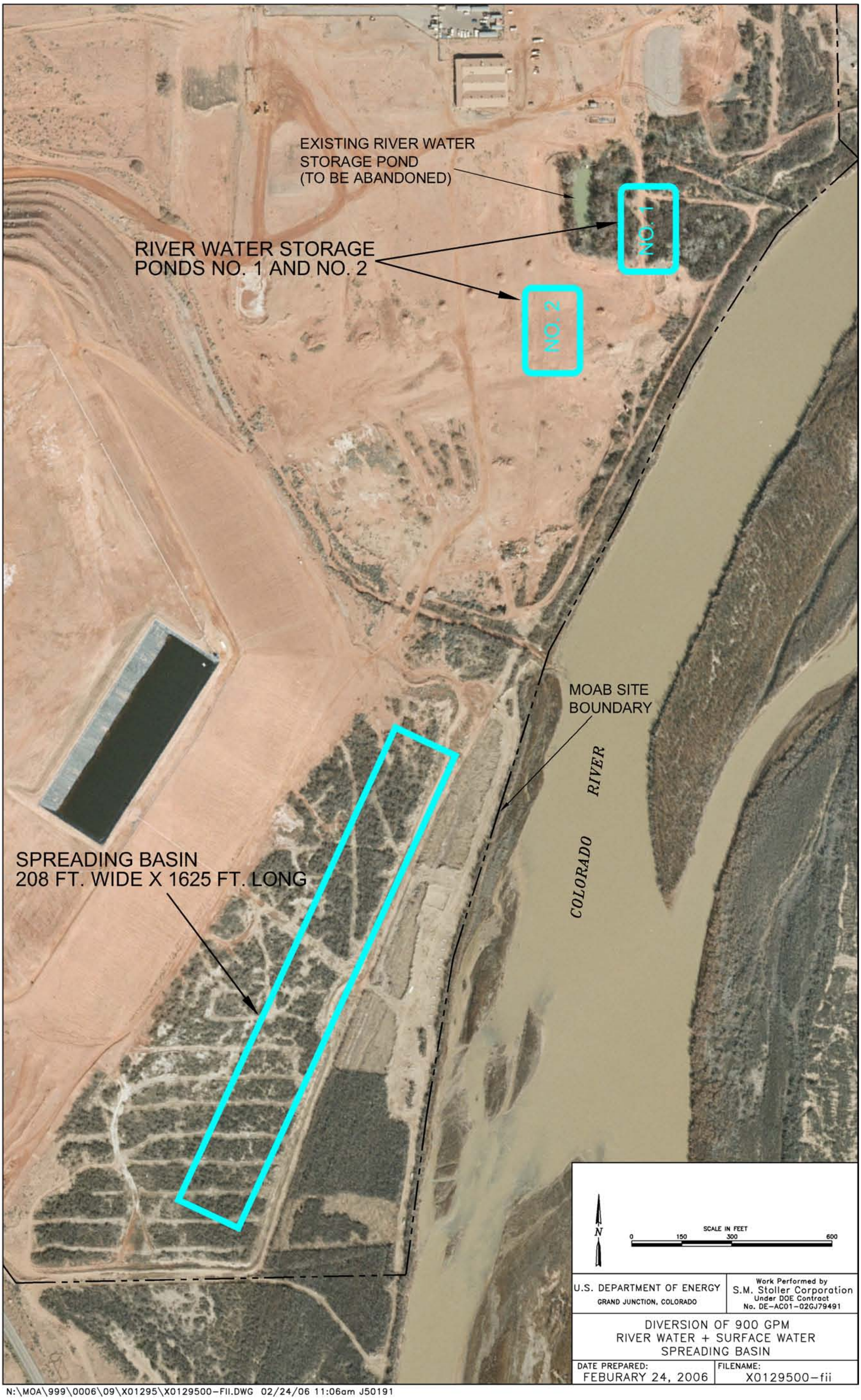

Figure 6-14. Alternative No.12B

7.0 Comparison of Treatment Alternatives

This section compares the various treatment alternatives to each other using a ranking process, in which the lowest score determines the recommended alternative. The ranking process used is as follows:

Ammonia Treatment

- A score of 1 is given if the treatment alternative produces water with an ammonia concentration less than 3 mg/L;
- A score of 2 is given if the alternative injects water with an ammonia concentration less than 3 mg/L; and
- If the ammonia concentration was not less than 3 mg/L, the alternative is given a score of 3.

Capital Cost

- If the alternative has an estimated capital cost of less than $1 million, it is given a score of 1;
- Between $1 and 3 million, the score is 2;
- Between $3 and 5 million, the score is 3;
- Between $5 and 7 million, the score is 4; and
- Greater than $7 million, the score is 5.

O&M Costs

- If the estimated cost is less than $250,000 per year, the score is 1;
- Between $250,000 and $1 million per year, the score is 2; and
- Greater than $1 million per year, the score is 3.

Safety

- A low safety risk is given a score of 1;
- A low to medium safety risk is given a score of 2; and
- A medium safety risk is given a score of 3.

Treatment Alternative

- If a treatment alternative does not require any pilot plant or similar optimization steps such as ground water modeling, the score is 1;
- A score of 2 is given when only one treatment technology required a pilot plant or similar optimization steps; and

- A score of 3 is given when more than one treatment technology required a pilot plant or similar optimization steps.

The ranking results, provided in Table 7−1, show that the recommended alternative would be to inject 150 gpm of Colorado River water directly into the shallow alluvial aquifer near backwater areas of affected ammonia discharge. This alternative has the lowest capital and O&M costs. Furthermore, this alternative poses a low safety risk to workers. Additional ground water modeling is recommended under this alternative to assess the probable ground water and near-shore surface concentrations in the Colorado River resulting from injection of the Colorado River water.

A Value Engineering (VE) assessment was conducted on the draft Alternatives Analysis report. The objectives and outcomes for the VE analysis are:

- Use VE as a valuable tool to generate a range of solutions to engineering problems and to evaluate the best solution to satisfy project needs.

- Select an alternative for the problem that meets the regulations and that will gain acceptance by the U.S. Nuclear Regulatory Commission (NRC), the State of Utah, and others.

- Determine a phased concept of treatment that addresses the strict cleanup objectives, considers the life of the project, and addresses potential changes in land use.

- Select an alternative that meets the objectives of the Biological Opinion from the U.S. Fish and Wildlife Service (USF&WS)—within 10 years to be protective for the endangered fish in the Colorado River.

The problem was defined as the following:

Ammonia concentrations in the low-water and backwater areas next to the site, along the west bank of the Colorado River, render these areas not protective for endangered fish. DOE is obligated by the Biological Opinion from the USF&WS to establish conditions that are protective within 10 years. DOE must have some active strategy to fulfill this obligation. Further, the potential exists to avoid extended, long-term ground water remediation (about 75 years) of the aquifer (this aquifer is not a drinking water source and may qualify for supplemental standards due to limited yield).

The recommendations from the VE assessment are:

- Divert up to 150 gpm from the Colorado River, pass it through in-line filtration, and inject the filtered water into a well field located adjacent to the river. The injection area near the river would provide dilution to the backwater channels with the potential for endangered fish habitat. (This action constitutes Alternative 9A.)
- Divert an additional 900 gpm from the Colorado River and route it through a surface water infiltration system located between the river and the tailings pile. (This constitutes Alternative 12B.)

- Place an extraction well field between the toe of the pile and the proposed surface water infiltration system to intercept contaminated ground water under and immediately downgradient of the pile and place this water in a lined evaporation pond. The evaporation pond could use enhanced evaporation methods (e.g., TurboMist) that could significantly reduce the pond size.

The evaluation process and alternatives considered are provided in Appendix C.

Based upon the VE assessment recommendations, additional modeling, engineering data, and equipment demonstration are needed. Ground water modeling is required to assess capture zones for the new extraction wells adjacent the eastern toe of the tailings pile, to determine plume transport times, and to predict ground water and near-shore surface concentrations in the river as a result of the surface water infiltration system. Adequate field investigations of soil and aquifer conditions are critical to the successful design of surface water infiltration systems. Field verification of soil conditions and permeabilities at the actual site are mandatory. Field measurements of infiltration rate or permeability using large basins (10 ft by 20 ft) are favored over standard infiltrometer testing because the vertical permeability can be overestimated using infiltrometers. Testing should be conducted during the coldest time of the year (November through February) under conditions of minimum evaporation (calm and cloudy), using the Colorado River water after settling.

The evaporation pond system designed is based upon using a spray-enhanced evaporation system that reduced the size of the evaporation by one-third over a conventional evaporation pond. An alternate approach may reduce size of the evaporation pond from 22 acres per pond to potentially as small as 6 acres per pond. Turbo-Mist evaporators provide advanced evaporation solutions to wastewater management, reduction, and reclamation. TurboMist evaporators are manufactured by Slimline Manufacturing, LTD. To achieve this size reduction in the evaporation ponds, the Turbo-Mist evaporators performance data need to be demonstrated using the existing evaporation pond at Moab. Recommendations are to develop a test plan, demonstrate the evaporator on site, and prepare a demonstration report that includes design data for the new evaporation pond system.

Table 7-1. Alternatives Comparison

Treatment Alternative	Meet Ground Water Remediation Objective	Capital Cost	O&M Cost	Safety	Implementation Factors and Limitations	Overall Score
No. 1: Extraction wells followed by well injection into or below the Paradox Fm (150 gpm)	3	1 – 3	1 – 2	1 – 2	2 – 3	8 – 13
No. 2: Extraction wells followed by evaporation ponds (150 gpm)	3	4	1	1	2	11
No. 3: Extraction wells followed by ammonia stripping and ion-exchange treatment with disposal by well injection into or below the Paradox Fm (150 gpm)	1	4 – 5	3	3	3	14 – 15
No. 4: Extraction wells followed by ammonia stripping and ion-exchange treatment with disposal by shallow well injection (150 gpm)	1	4	3	3	3	14
No. 5: Extraction wells followed by ammonia stripping and ion-exchange treatment with disposal into an infiltration gallery (150 gpm)	1	4	3	3	3	14
No. 6: Extraction wells followed by ammonia stripping and nitrification treatment with disposal by well injection into or below the Paradox Fm (150 gpm)	1	4 – 5	3	2	3	13 – 14
No. 7: Extraction wells followed by ammonia stripping and nitrification treatment with disposal by shallow well injection (150 gpm)	1	4	3	2	3	13
No. 8: Extraction wells followed by ammonia stripping and nitrification treatment with disposal into an infiltration gallery (150 gpm)	1	4	3	2	3	13
No. 9A: Divert Colorado River water into injection wells in the alluvial aquifer (150 gpm)	2	1	1	1	2	7
No. 9B: Divert Colorado River water into infiltration gallery above the alluvial aquifer (150 gpm)	2	1	1	1	2	7

Table 7–1(continued). Alternative Comparison

Treatment Alternative	Meet Ground Water Remediation Objective	Capital Cost	O&M Cost	Safety	Implementation Factors and Limitations	Overall Score
No. 10: Extraction wells (150 gpm plus divert 750 gpm of Colorado River water) followed by nitrification treatment with disposal by well injection into the alluvial aquifer (900 gpm)	1	3	2	1	2	9
No. 11: Extraction wells (150 gpm plus divert 750 gpm of Colorado River water) followed by nitrification treatment with disposal into an infiltration gallery (900 gpm)	1	2	2	1	2	8
No. 12A: Divert 2 cfs of Colorado River water into wetlands above the alluvial aquifer	2	4	1	1	2	10
No. 12B: Divert 2 cfs of Colorado River water into spreading basin above the alluvial aquifer	2	1	1	1	2	7

End of current text

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Appendix A

Well-Specific Information

and Alternatives Estimated Costs

Moab Groundwater Well Fields

Individual Pumping Rates and Ammonia Concentrations
(from Fall 2004 Performance Assessment of the Ground Water Interim Action Well Fields at the Moab, Utah Project Site)

Well Number	Average Pumping Rate, gpm	Ammonia-June 2004	Ammonia-July 2004	Ammonia-Aug 2004	Ammonia-Sept 2004	Ammonia-Oct 2004	Average Concentration, mg/l	Minimum Ammonia Concentration, mg/l	Maximum Ammonia Concentration, mg/l	2004 Minimum Ammonia Concentration, mg/l	2004 Maximum Ammonia Concentration, mg/l
470	4.2	960	1000	990	840	650	888			710	1100
471	3.3	890	1100	1100	910	740	948			500	1000
472	3.03	780	940	990	880	700	858			670	1000
473	1.81	770	810	920	900	660	812			620	1100
474	2.15	710	860	960	930	770	846			600	1100
475	2.46	640	810	890	890	700	786			570	1100
476	1.55	650	840	860	850	760	792			560	1100
477	1.8	650	750	810	710	680	720			540	1200
478	2.29	760	1400	920	840	710	926			650	1300
479	2.27	780	760	840	840	720	788			620	1400
570 shallow	1.85						1600			510	1700
572 shallow	2.23						1050			970	1200
574 shallow	1.5						870			710	1100
576 shallow	1.34						980			520	1300
578 shallow	1.27						740			840	1100
Total Pump Capacity	33.05						907	640	1600	500	1700

Average Pumping rate per well	2.20

From Moab SOW Alternatives Analysis

Extract 150 gpm of contaminated water with an ammonia concentration of 1000 mg/l

From Site Observation Work Plan, page 9-1

Ammonia concentration of 800 mg/l and a treatment goal of 3 mg/l of ammonia

Uranium concentration of 2 mg/l above saltwater interface and 3 mg/l below salt water interface

Recommendation for alternatives analysis design parameters

Flowrate per extraction well	2.5 gpm
Number of extraction wells	60
Groundwater Ammonia concentration	900 mg/l as NH_3
Treated Ammonia concentration	3 mg/l as NH_3
Groundwater pH	6.8
Groundwater Uranium concentration	2.6 mg/l

Total Dissolved Solids Concentrations by Well

Well Number	Total Dissolved Solids, mg/l , June 2004	Total Dissolved Solids, mg/l , July 2004	Total Dissolved Solids, mg/l , August 2004	Total Dissolved Solids, mg/l , Sept 2004	Total Dissolved Solids, mg/l , Oct 2004	Average Concentration, mg/l	2004 Minimum Total Dissolved Solids Concentration, mg/l	2004 Maximum Total Dissolved Solids Concentration, mg/l
470	22000	24000	21000	22000	18000	21400		
471	20000				22000	21000		
472	19000	22000	22000	23000	19000	21000		
473	19000	17000	20000	22000	17000	19000		
474	17000	19000	21000	22000	19000	19600		
475	17000	18000	20000	21000	17000	18600		
476	15000	19000	20000	20000	18000	18400		
477	17000	18000	18000	17000	17000	17400		
478	17000		20000	21000	18000	19000		
479	17000	17000	18000	20000	18000	18000		
570 shallow						45500		
572 shallow						36500		
574 shallow						32500		
576 shallow						29500		
578 shallow						20000		
						23826.7	15000	45500

Rounded to 24,000 since raw data was to the nearest 10,000 mg/l

Uranium Concentration by Well

Well Number	Uranium-June 2004	Uranium-July 2004	Uranium-Aug 2004	Uranium-Sept 2004	Uranium-Oct 2004	Average Concentration, mg/l	2004 Minimum Uranium Concentration, mg/l	2004 Maximum Uranium Concentration, mg/l
470	3.4	3	2.7	2.7	2.1	2.78		
471	3.3	2.7	2.5	2.5	2	2.6		
472	3.2	2.6	2.8	2.8	1.9	2.66		
473	3.1	2.5	3	3.1	2.3	2.8		
474	2.9	2.8	3.1	3.5	2.3	2.92		
475	3	2.9	3.1	3.2	2.3	2.9		
476	3.1	3.2	3.2	3.1	2.2	2.96		
477	3	2.9	3	2.9	2.3	2.82		
478	2.9	2.7	2.8	2.8	2.2	2.68		
479	3	2.7	2.6	2.7	2.3	2.66		
570 shallow						2.05		
572 shallow						2.2		
574 shallow						2.45		
576 shallow						2.7		
578 shallow						2.5		
						2.6	1.9	3.5

pH Concentration by Well

Well Number	pH-June 2004	pH-July 2004	pH-Aug 2004	pH-Sept 2004	pH-Oct 2004	Average Concentration	2004 Minimum pH Concentration	2004 Maximum pH Concentration
470	6.75	6.82	6.82	6.79	6.84	6.80	6.62	7.02
471	6.79	6.79	6.79	6.75	6.82	6.79	6.59	6.97
472	6.82	6.86	6.82	6.79	6.87	6.83	6.61	6.99
473	6.79	6.83	6.76	6.73	6.85	6.79	6.52	6.98
474	6.82	6.86	6.74	6.74	6.82	6.80	6.52	6.97
475	6.82	6.82	6.79	6.72	6.81	6.79	6.51	6.94
476	6.83	6.84	6.81	6.76	6.79	6.81	6.54	7
477	6.81	6.8	6.77	6.68	6.78	6.77	6.52	6.92
478	6.71	6.82	6.77	6.65	6.74	6.74	6.11	6.95
479	6.8	6.74	6.71	6.67	6.71	6.73	6.5	6.9
570 shallow						6.71	6.68	6.75
572 shallow						6.69	6.64	6.81
574 shallow						6.9	6.75	7.31
576 shallow						6.75	6.72	6.87
578 shallow						6.83	6.76	6.91
						6.8	6.11	7.02

Alternatives Analysis for Long-Term Ground Water Remediation
Moab Site

Ground Water Remediation Alternative 1

150 gpm from Extraction Wells plus Well Injection into Paradox Formation (500 ft depth)

Capital Cost for Construction		Cost
	Extraction Well System	$690,000
	Paradox Formation Well System	$110,000
Total		$800,000
Annual Operations and Maintenance Costs		Cost
	Labor	$130,000
	Energy	$16,000
Total		$146,000

Alternatives Analysis for Long-Term Ground Water Remediation
Moab Site

Ground Water Remediation Alternative 2

150 gpm from Extraction Wells plus Evaporation Pond

Capital Cost for Construction		Cost
	Extraction Well System	$690,000
	Evaporation Pond System	$6,100,000
	Piping to Evap. Ponds	$29,000
Total		$6,819,000

Annual Operations and Maintenance Costs		Cost
	Labor	$195,000
	Energy	$21,000
Total		$216,000

Ground Water Remediation Alternative 3

150 gpm from Extraction Wells treated by Air Stripping and Ion Exchange plus Well Injection into Paradox Formation

Capital Cost for Construction		Cost
	Extraction Well System	$690,000
	Air Stripping Treatment System	$4,336,000
	Ion Exchange Treatment System	$541,000
	Paradox Formation Well System (500 ft depth)	$110,000
Total		$5,677,000

Annual Operations and Maintenance Costs		Cost
	Labor	$598,000
	Energy (Electricity and Natural Gas)	$587,000
	Chemicals	$99,000
Total		$1,284,000

Ground Water Remediation Alternative 4

150 gpm from Extraction Wells treated by Air Stripping and Ion Exchange plus Shallow Well Injection into Alluvial Aquifer

Capital Cost for Construction		Cost
	Extraction Well System	$690,000
	Air Stripping Treatment System	$4,336,000
	Ion Exchange Treatment System	$541,000
	Shallow Well Injection System	$445,000
Total		$6,012,000
Annual Operations and Maintenance Costs		Cost
	Labor	$598,000
	Energy (Electricity and Natural Gas)	$587,000
	Chemicals	$99,000
Total		$1,284,000

Ground Water Remediation Alternative 5

150 gpm from Extraction Wells treated by Air Stripping and Ion Exchange plus Infiltration Gallery above Alluvial Aquifer

Capital Cost for Construction		Cost
	Extraction Well System	$690,000
	Air Stripping Treatment System	$4,336,000
	Ion Exchange Treatment System	$541,000
	Infiltration Gallery System	$110,000
Total		$5,677,000

Annual Operations and Maintenance Costs		Cost
	Labor	$598,000
	Energy (Electricity and Natural Gas)	$587,000
	Chemicals	$99,000
Total		$1,284,000

Ground Water Remediation Alternative 6

150 gpm from Extraction Wells treated by Air Stripping and Nitrification plus Well Injection into Paradox Formation

Capital Cost for Construction		Cost
	Extraction Well System	$690,000
	Air Stripping Treatment System	$4,336,000
	Nitrification Treatment System	$53,000
	Paradox Formation Well System (500 ft depth)	$110,000
Total		$5,189,000

Annual Operations and Maintenance Costs		Cost
	Labor	$533,000
	Energy	$595,000
	Chemicals	$81,000
Total		$1,209,000

Ground Water Remediation Alternative 7

150 gpm from Extraction Wells treated by Air Stripping and Nitrification plus Shallow Well Injection into Alluvial Aquifer

Capital Cost for Construction		Cost
	Extraction Well System	$690,000
	Air Stripping Treatment System	$4,336,000
	Nitrification Treatment System	$53,000
	Shallow Well Injection System	$445,000
Total		$5,524,000
Annual Operations and Maintenance Costs		Cost
	Labor	$506,000
	Energy	$595,000
	Chemicals	$81,000
Total		$1,182,000

Ground Water Remediation Alternative 8

150 gpm from Extraction Wells treated by Air Stripping and Nitrification plus Infiltration Gallery above Alluvial Aquifer

Capital Cost for Construction		Cost
	Extraction Well System	$690,000
	Air Stripping Treatment System	$4,336,000
	Nitrification Treatment System	$53,000
	Infiltration Gallery System	$110,000
Total		$5,189,000
Annual Operations and Maintenance Costs		Cost
	Labor	$533,000
	Energy	$595,000
	Chemicals	$81,000
Total		$1,209,000

Ground Water Remediation Alternative 9A

150 gpm from Colorado River plus Shallow Well Injection into Alluvial Aquifer

Capital Cost for Construction		Cost
	River Water System	$18,000
	Shallow Well Injection System	$445,000
Total		$463,000
Operations and Maintenance Costs		Cost
	Labor	$130,000
	Energy	$6,000
Total		$136,000

Ground Water Remediation Alternative 9B

150 gpm from Colorado River plus Infiltration Gallery above Alluvial Aquifer

Capital Cost for Construction		Cost
	River Water System	$18,000
	Infiltration Gallery System	$103,000
Total		$121,000
Operations and Maintenance Costs		Cost
	Labor	$130,000
	Energy	$6,000
Total		$136,000

Ground Water Remediation Alternative 10

150 gpm from Extraction Wells plus 750 gpm from Colorado River treated by Nitrification plus Shallow Well Injection into Alluvial Aquifer

Capital Cost for Construction		Cost
	Extraction Well System	$690,000
	River Water System	$287,000
	Nitrification Treatment System	$549,000
	Shallow Well Injection System	$2,600,000
Total		$4,126,000
Annual Operations and Maintenance Costs		Cost
	Labor	$130,000
	Energy	$137,000
	Chemicals	$425,000
Total		$692,000

Ground Water Remediation Alternative 11

150 gpm from Extraction Wells plus 750 gpm from Colorado River treated by Nitrification plus Infiltration Gallery above Alluvial Aquifer

Capital Cost for Construction		Cost
	Extraction Well System	$690,000
	River Water System	$287,000
	Nitrification Treatment System	$549,000
	Infiltration Gallery System	$503,000
Total		$2,029,000
Annual Operations and Maintenance Costs		Cost
	Labor	$130,000
	Energy	$137,000
	Chemicals	$425,000
Total		$692,000

Ground Water Remediation Alternative 12A

Diversion of 2 cfs of Colorado River Water followed by Wetlands Percolation above Alluvial Aquifer

Capital Cost for Construction		Cost
	River Water System	$291,000
	Wetlands	$5,900,000
Total		$6,191,000
Annual Operations and Maintenance Costs		Cost
	Labor	$130,000
	Energy	$20,411
Total		$150,411

Ground Water Remediation Alternative 12B

Diversion of 2 cfs of Colorado River Water followed by Spreading Basin Percolation above Alluvial Aquifer

Capital Cost for Construction		Cost
	River Water System	$291,000
	Spreading Basin	$120,000
Total		$411,000
Annual Operations and Maintenance Costs		Cost
	Labor	$130,000
	Energy	$20,411
Total		$150,411

End of current text

Appendix B

Detailed Cost Estimate

B.1 Extraction Well System

Extraction Wells Cost Estimate

Well	Well Type/Relative Depth	Diameter	Total Depth (ft bgs)
MOA-470	Extraction	4	21.3
MOA-471	Extraction	4	21.3
MOA-472	Extraction	4	21.3
MOA-473	Extraction	4	21.3
MOA-474	Extraction	4	21.3
MOA-475	Extraction	4	21.3
MOA-476	Extraction	4	21.3
MOA-477	Extraction	4	21.3
MOA-478	Extraction	4	25.5
MOA-479	Extraction	4	25.2
MOA-570	Extraction/Shallow	6	31.3
MOA-572	Extraction/Shallow	6	31.3
MOA-574	Extraction/Shallow	6	31.3
MOA-576	Extraction/Shallow	6	31.3
MOA-578	Extraction/Shallow	6	31.3
MOA-571	Extraction/Deep	6	41.3
MOA-573	Extraction/Deep	6	41.3
MOA-575	Extraction/Deep	6	41.3
MOA-577	Extraction/Deep	6	41.3
MOA-579	Extraction/Deep	6	41.3
	Average:	**5**	**29.2**

Wells 670-679 are extraction wells that were constructed as part of Configuration 3

Well Details:

Number of New Wells	30	
Diameter (average)	6	inches
Depth (average)	30	ft
Spacing	25	ft

From Operations, Maintenance and Performance Monitoring Plan for the Interim Action Groundwater Treatment System Moab, Utah, Site February 2004:

Wells developed using standard surge and bail techniques

Average Time (hrs/well)		2 hrs/well
Well Installation	Borings advanced using air-hammer percussion method	
Blank Casing	6 inch PVC Sch 40	
Well Screen	6 inch 0.01 Slotted PVC (Sch 40)	
Sump/End Cap	6-inch PVC Sch 40	
Seal	Bentonite Pellets	
Lower Pack	16-40 Silca Sand	
Drilling Method	Air Hammer Percussion (10 inch Dia)	
Sampling Method	Cyclone	
Sampling	Baseline - 2 rounds of sampling and analysis	
	Valves and sampling posts at each well	

Submersible pump for each well, equipped with thermal overload protection

Rate (gpm)	2.5
Head (ft)	30
Horsepower (hp)	1/3

Costs (from Environmental Remediation Cost Data-Assemblies 10th Annual Edition 2004)
Assumptions:
Safety Level D

Startup/Installation time	15	days
Number of wells to install	30	wells
Diameter of well	6	inch
Depth of well	30	ft

Costs for 150 gpm system:	**Unit Cost ($)**	**Unit**	**Total Cost ($)**	**Assumptions**
21,000 Gallon Steel Wastewater Holding Tank, Rental	1,200.00	month	1,200.00	1 time event
Mobilize/Demobilize Drilling Rig & Crew	2,855.00	lump sum	2,855.00	1 time event
Monitoring Well Slug Testing Equipment Rental	703.00	wk	2109.00	need for 3 weeks
Pumping Test	7553.00	each	226590.00	for 30 wells
Slug Test Equipment Rental, Day	175.71	day	2635.65	need for 15 days
Decontaminate Rig, Augers, Screen (Rental Equipment)	108.60	day	1629.00	need for 15 days
DOT Steel Drum, 55 Gallon	81.00	each	7290.00	3 drums/well for 30 wells
6-inch PVC Sch 40, Well Casing	17.73	LF	7,978.50	30 wells at 15' depths
6-inch PVC,Sch 40, Well Screen	32.01	LF	14,404.50	30 wells at 15' depths
6-inch PVC, Well Plug	97.41	LF	2,922.30	1 ft required for 30 wells
4-inch Submersible Pump, 0.3-7 GPM, Head <= 140', 1/3 hp, w/ controls	1,828.00	each	54,840.00	for 30 wells
Air Rotary, 10-inch Dia Borehole (Consolidated), Depth <=100 ft	68.50	LF	61,650.00	30 wells at 30' depths
Standby for Drilling	405.37	each	12,161.10	for 30 wells
Move Rig/Equipment Around Site	466.18	each	13,985.40	for 30 wells
Well Development Equipment Rental (weekly)	219.00	wk	657.00	need for 15 days

Load Supplies/Equipment	1,216.00	lump sum		1,216.00	1 time event
Furnish 55 Gallon Drum for Development/Purge Water	81.00	each		12,150.00	5 drums per well
6-inch Screen, Filter Pack	28.37	LF		12,766.50	30 wells at 15' depths
Surface Pad, Concrete, 4' x 4' x 4"	204.48	each		6,134.40	for 30 wells
10" Well, Portland Cement Grout	15.62	LF		4,686.00	30 wells at 10' depths
10" Well, Bentonite Seal	287.25	each		8,617.50	for 30 wells
Protective Enclosure with Cover	494.49	each		14,834.70	for 30 wells
Teflon Bailer, 1" Outside Diameter x 1', 80 cc	156.00	each		4,680.00	for 30 wells
Misc. Items:					
Ammonia Nitrogen (EPA 350.2), Water Analysis	27.00	each		810.00	for 30 wells
Liquid, Uranium Isotopic, Alpha Spectroscopy	127.00	each		3,810.00	for 30 wells
Misc. Valves and Fittings	1,500.00	lump sum		45,000.00	for 30 wells
		Total cost:	**$**	**527,612.55**	
Total Cost with Contigency (30%):			**$**	**685,896.32**	$ 22,863.21 per well
	Rounded to $690,000				

Operating Cost

Hp required	for 60 operating wells	**28.28571429**
kw-hr required per year (350 operating days per year)		**177249.60**
Power Cost (annual)		**$10,103.23**

End of current text

B.2 Evaporation Ponds

Moab Groundwater Alternatives Analysis

Evaporation Pond

Item	Quantity	Units	Unit price	Cost	
Piping to Evaporation Ponds					
PVC Pipe 4-inch Sch. 40	2700	feet	$7.38	$19,926	
Excavation	1200	cubic yards	$0.85	$1,020	
Backfill	1200	cubic yards	$1.11	$1,332	
			Subtotal	$22,278	
Contingency (30%)				$6,683	
			Total	$28,961	
			Rounded to $29,000		
Evaporation Ponds					
Primary HDPE, 40 mil	2458880	sq. feet	$0.23	$558,166	
Primary GCL	2458880	sq. feet	$0.26	$629,473	
GEONET	2458880	sq. feet	$0.26	$629,473	
Secondary GCL	2458880	sq. feet	$0.26	$629,473	
HDPE Installation Labor	273209	sq. yards	$1.85	$505,436	
GEONET Installation Labor	273209	sq. yards	$1.42	$387,957	
2 - GCL Installation Labor	546418	sq. yards	$1.38	$754,057	
Excavation - Ponds	100410	cubic yards	$1.75	$175,718	Based upon Moab Costs for Existing Evaporation Pond

Pipe Trench - Excavation	1200	cubic yards	$0.85	$1,020	
Backfill - Ponds	142270	cubic yards	$1.75	$248,973	Based upon Moab Costs for Existing Evaporation Pond
Pipe Trench - Backfill	1200	cubic yards	$1.11	$1,332	
PVC Pipe 4-inch Sch. 40	2700	feet	$7.38	$19,926	
PVC Pipe 2-inch Sch. 40	6800	feet	$3.20	$21,760	
PVC Pipe 6-inch Sch. 40	9060	feet	$10.60	$143,100	
30-hp, 750 gpm centrifugal pump	2	each	$5,419	$10,838	
			Subtotal	$4,669,637	
Contingency (30%)				$1,400,891	
			Total	$6,070,528	

Rounded to $6,100,000

Operating Cost

Electricity Cost for 30-hp, 750 gpm pump

Electricity consumed	187,992	kwh/yr
Electricity cost	$10,716	

Labor Cost

3 employees working 5-8 hr days per week

Labor Cost $195,000

B.3 Air Stripper System

Equipment Costs for Air Stripper/Ion Exchange Unit

Equipment	Item Number	Description/items included	Estimate Type	Quantity	Unit Cost	Total Cost	
Ground Water Storage Tank	1	HDPE Storage tank - 4500 gallon	Published Price	1	$ 7,630.00	$ 7,630.00	
	2	Tank Stand	Published Price	1	$ 1,935.00	$ 1,935.00	
	3	Pump		2	$ 2,500.00	$ 5,000.00	
					Subtotal		*$ 14,565.00*
Air Stripper	1	Inlet pH adjustment with NaOH. Metering system with in-line static mixer.	Budgetary from Vendor	1	included in total		
	2	Air stripper including: tower, pumps, blower, packing, water/air distributor, demister.	Budgetary from Vendor	1	included in total		
	3	Inlet pH adjustment with H_2SO_4. Metering system with in-line static mixer.	Budgetary from Vendor	1	included in total		
					Subtotal		*$ 200,000.00*
Chemical storgae tanks for PH adjustment	1	HDPE Storage tank - 4500 gallon	Published Price	2	$ 7,630.00	$ 15,260.00	
Sulfuric acid and sodium hydroxide chemical storage tanks	2	Tank Stand	Published Price	2	$ 1,935.00	$ 3,870.00	
	3	Pump		4	$ 2,500.00	$ 10,000.00	
					Subtotal		*$ 29,130.00*
Catalytic Oxidizer	1	Natural Gas Fired air heater.	Personal communication with Vendor	1	included in total		
	2	Catalytic Oxidizer.	Personal communication with Vendor	1	included in total		
	3	Heat exchange equipment for air stripper inlet water	Personal communication with Vendor	1	included in total		
					Subtotal		*$ 750,000.00*
Air Stripper Blow Down Tanks	1	HDPE Storage tank - 4500 gallon	Published Price	1	$ 7,630.00	$ 7,630.00	
	2	Tank Stand	Published Price	1	$ 1,935.00	$ 1,935.00	
	3	Pump		2	$ 2,500.00	$ 5,000.00	
					Subtotal		*$ 14,565.00*

Ion Exchange System		Two 36 inch Vertical ion exchange units in parrallel		2	$53,400.00	$ 106,800.00		
					Subtotal		$	-
IX regenerant and blowdown storage tanks	1	HDPE Storage tank - 4500 gallon	Published Price	3	$ 7,630.00	$ 22,890.00		
	2	Tank Stand	Published Price	3	$ 1,935.00	$ 5,805.00		
	3	Pump		4	$ 2,500.00	$ 10,000.00		
					Subtotal		*$*	-
Groundwater injection storage tanks	1	HDPE Storage tank - 4500 gallon	Published Price	1	$ 7,630.00	$ 7,630.00		
	2	Tank Stand	Published Price	1	$ 2,500.00	$ 2,500.00		
					Subtotal		*$*	-
						Total Capital Equipment Costs	**$1,008,260.00**	

Factors to Convert Delivered Equipment Costs into Fixed Capital Investments
From Perry's Chemical Engineering Handbook 6th Edition, Table 25-50

Details	Grass Roots Plant Fluid Processing	Estimated Costs		
Equipment Delivered	1	$	1,008,260.00	
--Installed	0.76	$	766,277.60	
Piping	0.33	$	332,725.80	
Structural Steel Foundation, reinforced concrete	0.28	$	282,312.80	
Electrical	0.09	$	90,743.40	
Instrumentation	0.13	$	131,073.80	
Battery limits building and services	0.45	$	453,717.00	
Excavation and site preparation	0	$	-	Include in foundation/concrete
Auxiliaries	included above			
Total physical plan	**3.04**	$	3,065,110.40	
Field Expenses	0.38	$	383,138.80	average added in per engineering estimate
Engineering	0.41	$	413,386.60	
Direct plant costs	**3.83**	$	3,861,635.80	
Contractor's fee, overhead, profit	0.17	$	171,404.20	
Contingency	0.3	$	302,478.00	
Total fixed capital investment	**4.3**	$	4,335,518	

Rounded to $4,336,000

Unit operation	Comodity	Unit cost	units	Quantity required	units	Total ($/year	Comments
All	Power	$ 0.057	$/kw-hr	821,554	kw-hr	$ 46,828.58	Assume operation at 50 weeks per year
pH Adjust	Sodium Hydroxide	$ 2.17	$/gal	35	Gal/day	$ 26,582.50	Assume operation at 50 weeks per year
pH Adjust	Sulfuric Acid	$ 1.37	$/gal	8.6	Gal/day	$ 4,124.73	Assume operation at 50 weeks per year
Catalytic Oxidizer	Natural Gas	$ 6.44	$/1000 cubic feet	9700	ft^3/hr	$ 524,964.00	Assume operation at 50 weeks per year inlcudes heat loss
Catalytic Oxidizer	Resin replacement	$ 150,000	dollars	0.33	resin replace/year	$ 50,000	Replace resin every three years.
Ion Exchange	Resin	$ 0.20	$/ton	103	yearly resin replace	$ 21	Replace resin annually
Ion Exchange	Regenerant	$ 0.20	$/pound	250	#/day	$ 17,500.00	Assume operation at 50 weeks per year
				Total		$ 670,020.36	
			Air stripper	Energy		$ 571,792.58	
			Air stripper	Chemical		$ 80,707.18	
			Air stripper + IX	Energy		$ 571,792.58	
			Air stripper + IX	Chemical		$ 98,227.78	

Moab Groundwater Treatment Operations Cost Estimate
Cost Baseline in CY 2005 dollars.
Air Stripper Operations

Labor Resource	Unit	cost/unit	Personnel/shift	hours/shift	shift/day	day/week	weeks/year	Total hour/year	Cost/year
Day Crew Support	hours	$31.25	2	8	1	5	52	4,160.00	$130,000.00
Rotating Shift Operators	hours	$31.25	1	8	3	7	52	8,736.00	$273,000.00
Total								**12,896.00**	**$403,000.00**

Assumptions:
1) One person crew on the backshift. Utilization of remote dial-up trouble notification equipment and call-in of personnel as necessary.
2) Two additional personnel required for day shift (chemical transfers/makeups, operations supervision, maintenance support).
3) Estimate does not include premium pay for overtime and/or holidays.

End of current text

B.4 Ion Exchange System

Equipment Costs for Air Stripper/Ion Exchange Unit

Equipment	Item Number	Description/items included	Estimate Type	Quantity	Unit Cost	Total Cost	
Ground Water Storage Tank	1	HDPE Storage tank - 4500 gallon	Published Price	1	$ 7,630.00	$ 7,630.00	
	2	Tank Stand	Published Price	1	$ 1,935.00	$ 1,935.00	
	3	Pump		2	$ 2,500.00	$ 5,000.00	
					Subtotal		*$* -
Air Stripper	1	Inlet pH adjustment with NaOH. Metering system with in-line static mixer.	Budgetary from Vendor	1	included in total		
	2	Air stripper including: tower, pumps, blower, packing, water/air distributor, demister.	Budgetary from Vendor	1	included in total		
	3	Inlet pH adjustment with H_2SO_4. Metering system with in-line static mixer.	Budgetary from Vendor	1	included in total		
					Subtotal		*$* -
Chemical storgae tanks for PH adjustment	1	HDPE Storage tank - 4500 gallon	Published Price	2	$ 7,630.00	$ 15,260.00	
Sulfuric acid and sodium hydroxide chemical storage tanks	2	Tank Stand	Published Price	2	$ 1,935.00	$ 3,870.00	
	3	Pump		4	$ 2,500.00	$ 10,000.00	
					Subtotal		*$* -
Catalytic Oxidizer	1	Natural Gas Fired air heater.	Personal communication with Vendor	1	included in total		
	2	Catalytic Oxidizer.	Personal communication with Vendor	1	included in total		
	3	Heat exchange equipment for air stripper inlet water	Personal communication with Vendor	1	included in total		
					Subtotal		*$* -
Air Stripper Blow Down Tanks	1	HDPE Storage tank - 4500 gallon	Published Price	1	$ 7,630.00	$ 7,630.00	
	2	Tank Stand	Published Price	1	$ 1,935.00	$ 1,935.00	
	3	Pump		2	$ 2,500.00	$ 5,000.00	
					Subtotal		*$* -

Ion Exchange System		Two 36 inch Vertical ion exchange units in parrallel		2	$ 53,400.00	$ 106,800.00	
				Subtotal			$ 106,800.00
IX regenerant and blowdown storage tanks	1	HDPE Storage tank - 4500 gallon	Published Price	3	$ 7,630.00	$ 22,890.00	
	2	Tank Stand	Published Price	3	$ 1,935.00	$ 5,805.00	
	3	Pump		4	$ 2,500.00	$ 10,000.00	
				Subtotal			*$ 38,695.00*
Groundwater injection storage tanks	1	HDPE Storage tank - 4500 gallon	Published Price	1	$ 7,630.00	$ 7,630.00	
	2	Tank Stand	Published Price	1	$ 2,500.00	$ 2,500.00	
				Subtotal			*$ 10,130.00*
				Total Capital Equipment Costs			**$ 155,625.00**

Factors to Convert Delivered Equipment Costs into Fixed Capital Investments
From Perry's Chemical Engineering Handbook 6th Edition, Table 25-50

Details	Grass Roots Plant Fluid Processing		Estimated Costs	
Equipment Delivered	1	$	155,625.00	
--Installed	0.76	$	118,275.00	
Piping	0.33	$	51,356.25	
Structural Steel Foundation, reinforced concrete	0.28	$	43,575.00	
Electrical	0.09	$	14,006.25	
Instrumentation	0.13	$	20,231.25	
Battery limits building and services	0	$	-	included in air stripper
Excavation and site preparation	0	$	-	Include in foundation/concrete
Auxiliaries	included above			
Total physical plan	**2.59**	$	403,068.75	
Field Expenses	0	$	-	Included in air stripper
Engineering	0.41	$	63,806.25	
Direct plant costs	**3**	$	466,875.00	
Contractor's fee, overhead, profit	0.17	$	26,456.25	
Contingency	0.3	$	46,687.50	
Total fixed capital investment	**3.47**	$	540,018.75	

Rounded to $541,000

Unit operation	Comodity	Unit cost	units	Quantity required	units	Total ($/year	Comments
All	Power	$ 0.057	$/kw-hr	821,554	kw-hr	$ 46,828.58	Assume operation at 50 weeks per year
pH Adjust	Sodium Hydroxide	$ 2.17	$/gal	35	Gal/day	$ 26,582.50	Assume operation at 50 weeks per year
pH Adjust	Sulfuric Acid	$ 1.37	$/gal	8.6	Gal/day	$ 4,124.73	Assume operation at 50 weeks per year
Catalytic Oxidizer	Natural Gas	$ 6.44	$/1000 cubic feet	9700	ft^3/hr	$ 524,964.00	Assume operation at 50 weeks per year inlcudes heat loss
Catalytic Oxidizer	Resin replacement	$ 150,000	dollars	0.33	resin replace/year	$ 50,000	Replace resin every three years.
Ion Exchange	Resin	$ 0.20	$/ton	103	yearly resin replace	$ 21	Replace resin annually
Ion Exchange	Regenerant	$ 0.20	$/pound	250	#/day	$ 17,500.00	Assume operation at 50 weeks per year
				Total		$ 670,020.36	

Moab Groundwater Treatment Operations Cost Estimate
Cost Baseline in CY 2005 dollars.
Air Stripper + Ion Exchange Operations

Labor Resource	Unit	cost/unit	Personnel/shift	hours/shift	shift/day	day/week	weeks/year	Total hour/year	Cost/year
Day Crew Support	hours	$31.25	3	8	1	5	52	6,240.00	$195,000.00
Rotating Shift Opera	hours	$31.25	1	8	3	7	52	8,736.00	$273,000.00
Total								**14,976.00**	**$468,000.00**

Assumptions:

1) One person crew on the backshift. Utilization of remote dial-up trouble notification equipment and call-in of personnel as necessary.

2) Three additional personnel required for day shift. Two personnel for chemical transfers/makeups, operations supervision, and maintenance support. One person to cover additional support required for IX regenerant make-up, IX blowdown operations during the week, and is fully qualified as a back-up to the other operations personnel.

3) Estimate does not include premium pay for overtime and/or holidays.

End of current text

B.5 Nitrification System – 150 gpm

Moab Groundwater Alternatives Analysis

Nitrification - 150 gpm

Item	Quantity	Units	Unit price	Cost
Excavation	6750	cubic yards	$0.85	$5,738
Backfill	850	cubic yards	$3.57	$3,035
Grading	5278	sq. yards	$3.50	$18,472
20-hp surface aerator	1	each	$13,100	$13,100
			Subtotal	$40,344
Contingency (30%)				$12,103
			Total	$52,447
			Rounded to $53,000	

Operating Costs

Electricity Cost for 20-hp, surface aerators

Electricity consumed	131,924	kwh/yr
Electricity cost	$7,520	

Labor Cost

2 employees working 5-8 hr days per week

Labor Cost	$130,000

End of current text

B.6 Nitrification System – 900 gpm

Moab Groundwater Alternatives Analysis

Nitrification - 900 gpm

Item	Quantity	Units	Unit price	Cost
Excavation	28700	cubic yards	$0.85	$24,395
Backfill	7200	cubic yards	$3.57	$25,704
Grading	20000	sq. yards	$3.50	$70,000
30-hp surface aerators	8	each	$17,547	$140,376
Soda Ash Storage and Handling System	1	each	$150,000	$150,000
			Subtotal	$410,475
Contingency (30%)				$123,143
			Total	$533,618
			Rounded to $549,000	

Operating Costs

Electricity Cost for 30-hp, surface aerators

Electricity consumed	1,583,091	kwh/yr
Electricity cost	$90,236	

Soda Ash Cost

Soda Ash Used per year	1698	tons per year
Soda Ash Cost	$424,436	

Labor Cost

2 employees working 5-8 hr days per week

Labor Cost	$130,000

End of current text

B.7 River Water System – 750 gpm

Moab Groundwater Alternatives Analysis

Pumping 750 gpm of Colorado River Water

Item	Quantity	Units	Unit price	Cost
Pond Construction	1	Ea.	$167,523	$167,523
PVC Pipe 6-inch Sch. 40	3500	feet	$10.60	$37,100
Excavation	1166	cubic yards	$0.85	$991
Backfill	1166	cubic yards	$3.57	$4,163
30-hp 750 gpm centrifugal pump	2	each	$5,419.00	$10,838
			Subtotal	$220,615
Contingency (30%)				$66,184
			Total	$286,799
			Rounded to	$287,000

Operating Costs

Electricity Cost for 30-hp, pump

Electricity consumed	268,560	kwh/yr
Electricity cost	$15,308	

End of current text

B.8 Shallow Fresh Water Injection System – 150 gpm

150 gpm Shallow Injection Wells Cost Estimate

Well	Well Type/Relative Depth	Diameter	Total Depth (ft bgs)
MOA-470	Extraction	4	21.3
MOA-471	Extraction	4	21.3
MOA-472	Extraction	4	21.3
MOA-473	Extraction	4	21.3
MOA-474	Extraction	4	21.3
MOA-475	Extraction	4	21.3
MOA-476	Extraction	4	21.3
MOA-477	Extraction	4	21.3
MOA-478	Extraction	4	25.5
MOA-479	Extraction	4	25.2
MOA-570	Extraction/Shallow	6	31.3
MOA-572	Extraction/Shallow	6	31.3
MOA-574	Extraction/Shallow	6	31.3
MOA-576	Extraction/Shallow	6	31.3
MOA-578	Extraction/Shallow	6	31.3
MOA-571	Extraction/Deep	6	41.3
MOA-573	Extraction/Deep	6	41.3
MOA-575	Extraction/Deep	6	41.3
MOA-577	Extraction/Deep	6	41.3
MOA-579	Extraction/Deep	6	41.3
	Average:	**5**	**29.2**

Well Details:

Number of New Wells	20	
Diameter (average)	6	inches
Depth (average)	35	ft
Spacing	25	ft

From Operations, Maintenance and Performance Monitoring Plan for the Interim Action Groundwater Treatment System Moab, Utah, Site February 2004:

Wells developed using standard surge and bail techniques

Average Time (hrs/well)	2	hrs/well
Well Installation	Borings advanced using air-hammer percussion method	
Blank Casing	6 inch PVC Sch 40	

Well Screen	6 inch 0.01 Slotted PVC (Sch 40)
Sump/End Cap	6-inch PVC Sch 40
Seal	Bentonite Pellets
Lower Pack	16-40 Silca Sand
Drilling Method	Air Hammer Percussion (10 inch Dia)
Sampling Method	Cyclone
Sampling	Baseline - 2 rounds of sampling and analysis
	Valves and sampling posts at each well

Costs (from Environmental Remediation Cost Data-Assemblies 10th Annual Edition 2004)

Assumptions:

Safety Level D		
Startup/Installation time	25	days
Number of wells to install	20	wells
Diameter of well	6	inch
Depth of well	35	ft

Costs for 150 gpm system:	**Unit Cost ($)**	**Unit**	**Total Cost ($)**	**Assumptions**
21,000 Gallon Steel Wastewater Holding Tank, Rental	1,200.00	month	1,200.00	1 time event
Mobilize/Demobilize Drilling Rig & Crew	2,855.00	lump sum	2,855.00	1 time event
Monitoring Well Slug Testing Equipment Rental	703.00	wk	3515.00	need for 5 weeks
Pumping Test	7553.00	each	151060.00	for 20 wells
Slug Test Equipment Rental, Day	175.71	day	4392.75	need for 25 days
Decontaminate Rig, Augers, Screen (Rental Equipment)	108.60	day	2715.00	need for 25 days
DOT Steel Drum, 55 Gallon	81.00	each	6480.00	4 drums/well for 20 wells
6-inch PVC Sch 40, Well Casing	17.73	LF	7,092.00	20 wells at 20' depths
6-inch PVC,Sch 40, Well Screen	32.01	LF	9,603.00	20 wells at 15' depths
6-inch PVC, Well Plug	97.41	LF	1,948.20	1 ft required for 20 wells
Air Rotary, 10-inch Dia Borehole (Consolidated), Depth <=100 ft	68.50	LF	47,950.00	20 wells at 35' depths
Standby for Drilling	405.37	each	8,107.40	for 20 wells
Move Rig/Equipment Around Site	466.18	each	9,323.60	for 20 wells
Well Development Equipment Rental (weekly)	219.00	wk	1,095.00	need for 25 days
Load Supplies/Equipment	1,216.00	lump sum	1,216.00	1 time event
Furnish 55 Gallon Drum for Development/Purge Water	81.00	each	8,100.00	5 drums per well
6-inch Screen, Filter Pack	28.37	LF	8,511.00	20 wells at 15' depths
Surface Pad, Concrete, 4' x 4' x 4"	204.48	each	4,089.60	for 20 wells
10" Well, Portland Cement Grout	15.62	LF	3,124.00	20 wells at 10' depths
10" Well, Bentonite Seal	287.25	each	5,745.00	for 20 wells
Protective Enclosure with Cover	494.49	each	9,889.80	for 20 wells

Teflon Bailer, 1" Outside Diameter x 1', 80 cc	156.00	each	3,120.00	for 20 wells
10-hp 150 gpm centrifugal pump	3,033.00	each	6,066.00	2 pumps
Misc. Items:				
Ammonia Nitrogen (EPA 350.2), Water Analysis	27.00	each	540.00	for 20 wells
Liquid, Uranium Isotopic, Alpha Spectroscopy	127.00	each	2,540.00	for 20 wells
Total Dissolved Solids	11.85	each	237.00	for 20 wells
Misc. Valves and Fittings	1,500.00	lump sum	30,000.00	for 20 wells
		Total cost:	**$ 340,515.35**	
	Total Cost with Contigency (30%):		**$ 442,669.96**	$ 22,133.50 per well
	Rounded to $445,000			

Operating Cost

Hp required	150 gpm, centrifugal pump, 10 hp transfer pump	**10**
kw-hr required per year (350 operating days per year)		**89520.00**
Power Cost (annual)		**$5,102.64**

For the River Water Pumping alternative, 10-hp 150 gpm centrifugal pump is included in the River Water System cost. Reduce shallow injection wells cost to $327,000.

End of current text

B.9 Shallow Fresh Water Injection System – 900 gpm

900 gpm Shallow Injection Wells Cost Estimate

Well	Well Type/Relative Depth	Diameter	Total Depth (ft bgs)
MOA-470	Extraction	4	21.3
MOA-471	Extraction	4	21.3
MOA-472	Extraction	4	21.3
MOA-473	Extraction	4	21.3
MOA-474	Extraction	4	21.3
MOA-475	Extraction	4	21.3
MOA-476	Extraction	4	21.3
MOA-477	Extraction	4	21.3
MOA-478	Extraction	4	25.5
MOA-479	Extraction	4	25.2
MOA-570	Extraction/Shallow	6	31.3
MOA-572	Extraction/Shallow	6	31.3
MOA-574	Extraction/Shallow	6	31.3
MOA-576	Extraction/Shallow	6	31.3
MOA-578	Extraction/Shallow	6	31.3
MOA-571	Extraction/Deep	6	41.3
MOA-573	Extraction/Deep	6	41.3
MOA-575	Extraction/Deep	6	41.3
MOA-577	Extraction/Deep	6	41.3
MOA-579	Extraction/Deep	6	41.3
	Average:	**5**	**29.2**

Well Details:

Number of New Wells	120	
Diameter (average)	6	inches
Depth (average)	35	ft
Spacing	25	ft

From Operations, Maintenance and Performance Monitoring Plan for the Interim Action Groundwater Treatment System Moab, Utah, Site February 2004:

Wells developed using standard surge and bail techniques

Average Time (hrs/well)	2	hrs/well
Well Installation	Borings advanced using air-hammer percussion method	
Blank Casing	6 inch PVC Sch 40	

Well Screen	6 inch 0.01 Slotted PVC (Sch 40)
Sump/End Cap	6-inch PVC Sch 40
Seal	Bentonite Pellets
Lower Pack	16-40 Silca Sand
Drilling Method	Air Hammer Percussion (10 inch Dia)
Sampling Method	Cyclone
Sampling	Baseline - 2 rounds of sampling and analysis
	Valves and sampling posts at each well

Costs (from Environmental Remediation Cost Data-Assemblies 10th Annual Edition 2004)
Assumptions:

Safety Level D		
Startup/Installation time	160	days
Number of wells to install	120	wells
Diameter of well	6	inch
Depth of well	35	ft

Costs for 150 gpm system:	**Unit Cost ($)**	**Unit**	**Total Cost ($)**	**Assumptions**
21,000 Gallon Steel Wastewater Holding Tank, Rental	1,200.00	month	1,200.00	1 time event
Mobilize/Demobilize Drilling Rig & Crew	2,855.00	lump sum	2,855.00	1 time event
Monitoring Well Slug Testing Equipment Rental	703.00	wk	22496.00	need for 32 weeks
Pumping Test	7553.00	each	906360.00	for 120 wells
Slug Test Equipment Rental, Day	175.71	day	28113.60	need for 160 days
Decontaminate Rig, Augers, Screen (Rental Equipment)	108.60	day	17376.00	need for 160 days
DOT Steel Drum, 55 Gallon	81.00	each	38880.00	4 drums/well for 120 wells
6-inch PVC Sch 40, Well Casing	17.73	LF	42,552.00	120 wells at 20' depths
6-inch PVC,Sch 40, Well Screen	32.01	LF	57,618.00	120 wells at 15' depths
6-inch PVC, Well Plug	97.41	LF	11,689.20	1 ft required for 120 wells
Air Rotary, 10-inch Dia Borehole (Consolidated), Depth <=100 ft	68.50	LF	287,700.00	120 wells at 35' depths
Standby for Drilling	405.37	each	48,644.40	for 120 wells
Move Rig/Equipment Around Site	466.18	each	55,941.60	for 120 wells
Well Development Equipment Rental (weekly)	219.00	wk	7,008.00	need for 32 weeks
Load Supplies/Equipment	1,216.00	lump sum	1,216.00	1 time event
Furnish 55 Gallon Drum for Development/Purge Water	81.00	each	48,600.00	5 drums per well
6-inch Screen, Filter Pack	28.37	LF	51,066.00	120 wells at 15' depths
Surface Pad, Concrete, 4' x 4' x 4"	204.48	each	24,537.60	for 120 wells
10" Well, Portland Cement Grout	15.62	LF	18,744.00	120 wells at 10' depths
10" Well, Bentonite Seal	287.25	each	34,470.00	for 120 wells
Protective Enclosure with Cover	494.49	each	59,338.80	for 120 wells

Teflon Bailer, 1" Outside Diameter x 1', 80 cc	156.0	each	18,720.00	for 120 wells
40-hp 900 gpm centrifugal pump	5,883.0	each	11,766.00	2 pumps
Misc.				
Ammonia Nitrogen (EPA 350.2), Water Analysis	27.0	each	3,240.00	for 120 wells
Liquid, Uranium Isotopic, Alpha Spectroscopy	127.0	each	15,240.00	for 120 wells
Total Dissolved Solids	11.8	each	1,422.00	for 120 wells
Misc. Valves and Fittings	1,500.0	lump sum	180,000.00	for 115 wells
		Total cost:	**$ 1,996,794.20**	
		Total Cost with Contigency	**$ 2,595,832.46**	$ 21,631.94 per well

Operating Cost Rounded to

Hp	900 gpm, centrifugal pump, 40 hp transfer pump	**40**
kw-hr required per year (350 operating days per year)		**358080.00**
Power Cost (annual)		**$20,410.56**

End of current text

B.10 Infiltration Gallery – 150 gpm

Moab Groundwater Alternatives Analysis

Infiltration Gallery - 150 gpm

Item	Quantity	Units	Unit price	Cost
Clearing	2	acres	$617.02	$1,234
Excavation	19000	cubic yards	$0.85	$16,150
Backfill	19000	cubic yards	$1.11	$21,090
PVC pipe 4-inch, Sch. 40	6400	feet	$6.25	$40,000
10-hp, 150 gpm centrifugal pump	2	each	$3,033.00	$6,066
			Subtotal	$84,540
Contingency (30%)				$25,362
			Total	$109,902

Rounded to $110,000

Operating Costs

Electricity Cost for 10-hp pump

Electricity consumed	89,520	kwh/yr
Electricity cost	$5,103	

For the River Water Pumping alternative, 10-hp 150 gpm centrifugal pump is included in the River Water System cost. Reduce infiltration gallery cost to $103,000 for this alternative.

End of current text

B.11 Infiltration Gallery – 900 gpm

Moab Groundwater Alternatives Analysis

Infiltration Gallery - 900 gpm

Item	Quantity	Units	Unit price	Cost
Clearing	8	acres	$617.02	$4,936
Excavation	92100	cubic yards	$0.85	$78,285
Backfill	92100	cubic yards	$1.11	$102,231
PVC pipe 4-inch, Sch. 40	32190	feet	$6.25	$201,188
40-hp, 900 gpm centrifugal pumps	2	each	$5,883	$11,766
		Subtotal		$386,640
Contingency (30%)				$115,992
		Total		$502,632
		Rounded to $503,000		
Electricity Cost for 40-hp, pumps				
Electricity consumed			358,080	kwh/yr
Electricity cost			$20,411	

End of current text

B.12 Paradox Formation Injection Well

Paradox Formation Wells Cost Estimate

Well Details:

Number of New Wells	1	
Diameter (average)	6	inches
Depth (average)	500	ft

From Operations, Maintenance and Performance Monitoring Plan for the Interim Action Groundwater Treatment System Moab, Utah, Site February 2004:

Wells developed using standard surge and bail techniques

Well Installation	Mud Drilling
Blank Casing	6 inch PVC Sch 40
Well Screen	6 inch 0.01 Slotted PVC (Sch 40)
Sump/End Cap	6-inch PVC Sch 40
Seal	Bentonite Pellets
Lower Pack	16-40 Silca Sand
Drilling Method	Mud Rotary (10 inch Dia)
Sampling Method	Cyclone
Sampling	Baseline - 2 rounds of sampling and analysis
	Valves and sampling ports

Costs (from Environmental Remediation Cost Data-Assemblies 10th Annual Edition 2004)
Assumptions:

Startup/Installation time	90	hours	Use 3 weeks
Number of wells to install	1	wells	
Diameter of well	6	inch	
Depth of well	500	ft	

Costs for 150 gpm system:	Unit Cost ($)	Unit	Total Cost ($)	Assumptions
20,000 Gallon Steel Wastewater Holding Tank, Rental	1,200.00	month	1,200.00	1 time event
Mobilize/Demobilize Drilling Rig & Crew	2,701.00	lump sum	2,701.00	1 time event
Monitoring Well Slug Testing Equipment Rental	703.00	wk	2109.00	need for 3 weeks
Pumping Test	7553.00	each	7553.00	for 1 well
Slug Test Equipment Rental, Day	175.71	day	2635.65	need for 3 weeks
Decontaminate Rig, Augers, Screen (Rental Equipment)	108.60	day	1629.00	need for 3 weeks
DOT Steel Drum, 55 Gallon	81.00	each	4050.00	50 drums/well
6-inch PVC Sch 40, Well Casing	16.99	LF	8,495.00	500 feet to Paradox Formation
6-inch PVC,Sch 40, Well Screen	33.92	LF	1,356.80	40 foot well screen
6-inch PVC, Well Plug	95.48	LF	95.48	1 ft required for 15 wells
Mud Drilling, 10" Dia. Borehole, 500 feet	64.81	LF	32,405.00	
Standby for Drilling	386.13	each	5,791.95	assume 15 hours
Well Development Equipment Rental (weekly)	219.00	wk	219.00	need for 3 weeks
Load Supplies/Equipment	1,216.00	lump sum	1,216.00	1 time event
Furnish 55 Gallon Drum for Development/Purge Water	81.00	each	1,215.00	15 drums per well
6-inch Screen, Filter Pack	28.37	LF	1,134.80	40 foot well screen
Surface Pad, Concrete, 4' x 4' x 4"	204.48	each	204.48	for 1 well
10" Well, Portland Cement Grout	15.62	LF	156.20	1 well at 10' depths
10" Well, Bentonite Seal	287.25	each	287.25	for 1 well
Protective Enclosure with Cover	494.49	each	494.49	for 1 well
Teflon Bailer, 1" Outside Diameter x 1', 80 cc	156.00	each	156.00	for 1 well
10-hp, 150 gpm centrifugal pump	3,033.00	each	6,066.00	2 pumps

Misc. Items:

Ammonia Nitrogen (EPA 350.2), Water Analysis	27.00	each	27.00	for 1 well
Liquid, Uranium Isotopic, Alpha Spectroscopy	127.00	each	127.00	for 1 well
Total Dissolved Solids	11.85	each	11.85	for 1 well
Misc. Valves and Fittings	1,500.00	lump sum	1,500.00	for 1 well
		Total cost:	**$ 82,836.95**	
	Total Cost with Contigency (30%):		**$ 107,688.04**	

Operating Cost Rounded to $110,000

Hp required	150 gpm, centrifugal pump, 10 hp transfer pump	**10**
kw-hr required per year (350 operating days per year)		**89520.00**
Power Cost (annual)		**$5,102.64**

End of current text

B.13 River Water System – 150 gpm

Moab Groundwater Alternatives Analysis

Pumping 150 gpm of Colorado River Water

Item	Quantity	Units	Unit price	Cost
PVC Pipe 2-inch Sch. 40	2000	feet	$3.20	$6,400
Excavation	700	cubic yards	$0.85	$595
Backfill	700	cubic yards	$1.11	$777
10-hp 150 gpm centrifugal pump	2	each	$3,033.00	$6,066
			Subtotal	$13,838
Contingency (30%)				$4,151
			Total	$17,989
			Rounded to $18,000	

Operating Costs

Electricity Cost for 10-hp, pump

Electricity consumed	89,520	kwh/yr
Electricity cost	$5,103	

End of current text

B.14 River Water System – 750 gpm

Moab Ground Water Alternatives Analysis

Pumping 750 gpm of Colorado River Water

Item	Quantity	Units	Unit price	Cost
Pond Construction	1	EA.	$167,523	$167,523
PVC pipe 6-inch, Sch. 40	3500	ft	$10.60	$37,100
Pipe Trench Excavation	1,166	cubic yards	$0.85	$991
Pipe Trench Backfill and Compact	1,166	cubic yards	$3.57	$4,163
30-hp, 750 gpm centrifugal pumps	2	each	$5,419	$10,838
			Subtotal	$220,615
Contingency (30%)				$66,185
			Total	$286,800
			Rounded to	$287,000

Electricity Cost for 30-hp, pumps

Electricity consumed	268,560	kwh/yr
Electricity cost	$15,308	

End of current text

B.15 River Water System – 2 cfs

Moab Ground Water Alternatives
Analysis

Pumping 2 cfs of Colorado River Water

Item	Quantity	Units	Unit price	Cost
Pond Construction	1	EA.	$167,523	$167,523
PVC pipe 6-inch, Sch. 40	3500	ft	$10.60	$37,100
Pipe Trench Excavation	1,166	cubic yards	$0.85	$991
Pipe Trench Backfill and Compact	1,166	cubic yards	$3.57	$4,163
40-hp, 1000 gpm centrifugal pumps	2	each	$6,724	$13,448
			Subtotal	$223,225
Contingency (30%)				$66,967
			Total	$290,192
			Rounded to $291,000	

Electricity Cost for 40-hp, pumps

Electricity consumed	358,080	kwh/yr
Electricity cost	$20,411	

End of current text

B.16 Wetlands – 2 cfs

Moab Ground Water Alternatives
Analysis

Wetlands - 2 cfs

Item	Quantity	Units	Unit price	Cost
Inlet and Outlet Piping, PVC, 6-inch, Sch. 40	2,800	ft	$10.60	$29,680
Inlet and Outlet, valves and fittings	14	ea.	$1,500.00	$21,000
Inlet and Outlet Gabions	528	ea.	$1,125.00	$594,000
Clearing	15	acres	$321.15	$4,817
Excavation, wetlands	160,021	cubic yards	$0.85	$136,018
Soil Backfill, wetlands	22,621	cubic yards	$1.11	$25,109
Embankment Construction	10,663	cubic yards	$7.28	$77,627
Crushed Gravel	136,696	cubic yards	$24.51	$3,350,419
Surface Soil	9,114	cubic yards	$26.95	$245,622
Hydroseeding	12	acres	$537.62	$6,451
Grading	71,982	square yards	$0.62	$44,629
			Subtotal	$4,535,373
Contingency (30%)				$1,360,612
			Total	$5,895,984
			Rounded to $5,900,000	
Labor for O&M	2	FTE	$65,000	
Labor Cost			$130,000	

End of current text

B.17 Spreading Basin – 2 cfs

Moab Ground Water Alternatives
Analysis

Surface Spreading Basin - 2 cfs

Item	Quantity	Units	Unit price	Cost
Piping, 6-inch diameter, Sch. 40 PVC Perforated Distribution	1,625.0	ft	$10.60	$17,225
Clearing	9.8	acres	$321.15	$3,147
Dike Construction	5,016.0	cubic yards	$7.28	$36,516
Grading	55,556.0	square yards	$0.62	$34,445
			Subtotal	$91,333
Contingency (30%)				$27,400
			Total	$118,734
			Rounded to $120,000	
Labor for O&M	2	FTE	$65,000	
Labor Cost			$130,000	

End of current text

Appendix C

Value Engineering Alternatives Analysis for Long-Term Ground Water Strategy for the Moab UMTRA Site

Conducted Monday, February 6, 2006, 12:30–4:30, Mt. Garfield Room

Attendees:

Don Metzler, DOE
Ken Karp, Stoller
John Elmer, Stoller
Dave Peterson, Stoller
John Ford, Stoller
Al Laase, Consultant
Randy Richardson, Duratek
Don Vernon, Stoller
Cheri Bahrke, Stoller, Facilitator

Opening Statements:

Don Metzler and the team stated the following objectives and outcomes for this analysis:

1) Value Engineering is a valuable tool to generate a range of solutions to engineering problems and to evaluate the best solution to satisfy project needs.

2) Select an alternative for the problem that meets the regulations and that will gain acceptance by NRC, the State of Utah, and others.

3) Determine a phased concept of treatment that addresses the strict cleanup objectives, considers the life of the project, and addresses potential changes in land use.

4) Select an alternative that meets the objectives of the Biological Opinion from the USF&WS – within 10 years to be protective for the endangered fish at the Colorado River.

Problem Statement:

The problem was defined as the following: Ammonia concentrations in the surface water expressions in the low water and backwater areas next to the Colorado River renders these areas not protective for endangered fish. DOE is obligated by the Biological Opinion from the USF&WS to be protective within 10 years. DOE must have some active strategy to fulfill this obligation.

Mr. Metzler stated that the potential exists to avoid extended, long-term ground water remediation (~75 years) of the aquifer. He added that the aquifer is not a drinking water source and may qualify for supplemental standards due to limited yield.

Evaluation Process:

The group was provided a brief description of each alternative as presented in the *Alternatives Analysis for Long-Term Ground Water Remediation, Moab Site, Located Near Moab, Utah*. The alternatives were not discussed at length during these presentations. After the alternatives were presented, the group was asked if there were any additional alternatives for consideration. One additional alternative was added. The group then discussed the pros and cons of each alternative and consensus was reached on which alternatives could be eliminated from further consideration. Finally, the group determined what questions needed to be answered regarding the remaining alternatives so that a recommendation can be made to DOE for a solution to the problem.

Alternatives Considered:
The following is a list of the alternatives considered and, if they were eliminated, reasons for their elimination.

1) Extracting 150 gpm (contaminated) – injecting into deeper Paradox formation 5000-8000 ft below ground surface (bgs), top of Paradox approx. 5000 ft. bgs, Leadville Limestone at approx. 8000 bgs.

   This alternative would use the existing 30 wells and add 30 more for a total of 60 wells to extract the contaminated water. Injection would be accomplished with a single deep well.

   Pros:
   - Extraction wells and deep injection wells are "out of sight, out of mind"
   - No reason to treat, therefore no costs for treatment
   - Simple solution over the long term
   - Leadville injection is a complete solution
   - Provides maximum flexibility for the end state and future land use

   Cons:
   - Stakeholder concerns over failure of solution due to seismic activity
   - Stakeholder concerns over degraded ground water quality to area
   - Inability to sustain/maintain injection pressures
   - Need a clastic zone for successful injection – will not know until deep injection well is drilled – well ends up being a test (high cost/high risk)
   - Permitting the injection
   - High-energy usage

   Eliminated due to concerns over high cost and high degree of uncertainty about the deep injection well.

2) Extracting 150 gpm (contaminated) – pumping to two (2) 22-acre evaporation ponds.

   This alternative would use the existing 30 wells and add 30 more for a total of 60 wells to extract the contaminated water. The ponds were designed using the criteria of the existing pond on the pile. Discussion included adding some type of spray evaporation to look at potential to make the ponds smaller. In addition this alternative should further evaluate the potential to spray the water on the ground or to mix with clean river water.

   Pros:
   - Proven to eliminate contaminants
   - Low tech, few problems to go wrong
   - Covers all contaminants of concern

   Cons:
   - Have final disposal of infrastructure and pond liner(s) after the cell is closed
   - Footprint of ponds could be problematic to area needed for operations
   - Wildlife concerns for open contaminated water

   Held for further consideration in the recommendation.

3) Extracting 150 gpm – treating water by 1) air stripping and 2) ion exchange – then injecting effluent into a deep injection well.

This alternative would use the existing 30 wells and add 30 more for a total of 60 wells to extract the contaminated water. The ion exchange unit would use media appropriate for ammonia removal.

Pros:

- Leaves a relatively small footprint
- Treatment achieves 3 milligrams per liter (mg/L) cleanup goal for ammonia
- Treatment covers all contaminants of concern
- Treatment/disposal to deep well addresses concerns about ground water quality

Cons:

- No need to treat with deep injection as final disposal
- High cost of treatment systems and deep well
- Hi tech, much to break down
- Pilot test needed for proof of process
- Permits/reporting needed for air stripper, permit for deep injection
- Smell of operating treatment
- Constant operations and safety concerns

Eliminated due to concerns over high cost of set up and operations of treatment systems, and large uncertainties about the deep well disposal option.

4) Extracting 150 gpm – treating water by 1) air stripping and 2) ion exchange – then injecting treated water into the alluvial aquifer using shallow wells.

This alternative would use the existing 30 wells and add 30 more for a total of 60 wells to extract the contaminated water. The treatment is the same as Alternative 3. The treated water would be injected using 20 shallow wells near the southern property boundary.

Pros:

- Same as listed in Alternative 3

Cons:

- Same as listed in Alternative 3, and
- Well efficiency
- Uncertainty about State of Utah regulatory concerns, this option may push the normally immobile brine near the site's south boundary toward the river
- Does not treat uranium or other contaminants of concern

Eliminated due to high cost of set up and operation of treatment systems and the likely inability of gaining regulatory buy-in.

5) Extracting 150 gpm – treating water by 1) air stripping and 2) ion exchange – then injecting treated water into the alluvial aquifer using an infiltration gallery.

This alternative would use the existing 30 wells and add 30 more for a total of 60 wells to extract the contaminated water. The treatment is the same as Alternative 3. The treated water would be injected into the shallow portions of the alluvial aquifer using an infiltration gallery.

Pros:

- Same as Alternative 3

Cons:

- Same as Alternative 4

Eliminated due to high cost of set up and operation of treatment systems and the likely inability of gaining regulatory buy-in.

6) Extracting 150 gpm – treating water by 1) air stripping and 2) nitrification – then injecting treated water into a deep Paradox Formation well.

This alternative would use the existing 30 wells and add 30 more for a total of 60 wells to extract the contaminated water. It was determined that there is enough alkalinity in the ground water to not require inorganic carbon for the nitrification process. However, the process would leave approximately 500 mg/L of nitrate in the effluent.

Pros:

- Comparing treatment options, nitrification cheaper than ion exchange
- Lower technology risk
- Fewer safety concerns in operations, less chemical handling
- Reduced waste

Cons:

- Adds nitrate to the effluent at 10 times the standard
- Unsure of how added nitrate would affect the fish DOE is obligated to protect
- Uranium passes through the system

Eliminated due to high cost of the set up and operations of treatment operation and the uncertainty of the deep well disposal method.

7) Extracting 150 gpm – treating water by 1) air stripping and 2) nitrification – then injecting treated water into shallow injection wells near the southern boundary of the property.

This alternative would use the existing 30 wells and add 30 more for a total of 60 wells to extract the contaminated water. It was determined that there is enough alkalinity in the ground water to not require inorganic carbon for the nitrification process. However, this process would leave approximately 500 mg/L of nitrate in the effluent.

Pros:

- Comparing treatment options, nitrification is cheaper than ion exchange
- Lower technology risk
- Fewer safety concerns in operations, less chemical handling
- Reduced waste

Cons:

- Adds nitrate to the effluent at 10 times the standard
- Unsure of how added nitrate would affect the fish DOE is obligated to protect
- Uranium passes through the system
- Permit injection
- Uncertainty about State of Utah regulatory concerns, this option may push the normally immobile brine toward the river
- Eliminated due to high cost of set up and operations of treatment systems and the potential lack of buy-in for injection

8) Extracting 150 gpm – treating water by 1) air stripping and 2) nitrification – then injecting treated water using an infiltration gallery.

This alternative would use the existing 30 wells and add 30 more for a total of 60 wells to extract the contaminated water. It was determined that there is enough alkalinity in the ground water to not require inorganic carbon for the nitrification process. However, this process would leave approximately 500 mg/L of nitrate in the effluent.

Pros:

- Comparing treatment options, nitrification is cheaper than ion exchange
- Lower technology risk
- Fewer safety concerns in operations, less chemical handling
- Reduced waste

Cons:

- Adds nitrate to the effluent at 10 times the standard
- Unsure of how added nitrate would affect the fish DOE is obligated to protect
- Uranium passes through the system
- Permit injection
- Uncertainty about State of Utah regulatory concerns, this option may simply push the brine toward the river

Eliminated due to high cost of set up and operations of treatment systems and the potential lack of buy-in for injection.

9) A. Diverting 150 gpm clean water from Colorado River – then injecting diverted water into 60 shallow wells along the river.

This alternative would use the existing 30 wells and add 30 more for a total of 60 wells to inject the water to flush contamination.

Pros:

- Least expensive option
- DOE has existing water rights to divert river water
- Meets objective of biological option for fish
- Dilutes the contamination in the ground water that discharges to the ecologically sensitive part of river
- Solution is enhanced by irrigation in nearby vegetation test plots
- Simple, eliminates treatment systems
- Incidental biodegradation

Cons:

- There is no mass removal
- Does not meet stakeholder concerns on treating contaminated ground water
- Will need settling pond prior to injection
- Unsure of where contamination is moved (need more modeling)
- Maintaining injection well efficiency

9) B. Diverting 150 gpm clean water from Colorado River – then injecting diverted water into a French drain/trench close to the river.

Pros:

- Same as 9A, plus
- Less maintenance than well injection option
- Fewer problems with efficiency

Cons:

- No mass removal
- Does not meet stakeholder concerns on contaminated ground water
- Will need settling pond prior to injection
- Unsure of where contamination is moved

These alternatives were held for further consideration in the recommendation.

10) Extracting 150 gpm contaminated water from the alluvial aquifer and blending it with 750 gpm clean water from the Colorado River – then treating the water with nitrification prior to injecting back into the aquifer using 120 shallow wells.

Pros:

- Increases the hydraulic gradient toward the river
- Nitrification more efficient than ion exchange

Cons:

- High cost of wells
- High cost of O&M of the wells
- Must supplement the system to address the alkalinity
- May need additional wells to achieve injection goals

- Maintaining well efficiency
- Does not treat other contaminants of concern
- Large footprint

Eliminated due to high cost of wells and treatment.

11) Extracting 150 gpm contaminated water from the alluvial aquifer and blending it with 750 gpm clean water from the Colorado River – then treating the water with nitrification prior to injecting back into the aquifer using an infiltration gallery.

Pros:

- Increases the hydraulic gradient toward the river
- Nitrification more efficient than ion exchange

Cons:

- High cost of wells
- High cost of O&M of the infiltration gallery
- Must supplement the system to address the alkalinity
- May need additional wells to achieve injection goals
- Maintaining efficiency of the infiltration gallery
- Large footprint

Eliminated due to high cost of treatment and infiltration gallery.

12) A. Extracting 150 gpm contaminated water from the alluvial aquifer and placing the water in a constructed wetlands.

This alternative could prove useful as a treatment/disposal option for Alternatives 3 and 6. The primary wetland could be partially lined and would handle the amount of water being extracted for placement in the wetland. The secondary wetland could be allowed to leak to the alluvial aquifer and to discharge to the Colorado River.

Pros:

- Inexpensive and simple solution
- The Environmental protection Agency (EPA) likes this approach
- Potentially treats nitrates and metals
- Depression from the cell would exist after remediation for use in building wetlands
- Site-specific, native species could help with the solution

Cons:

- Unsure if it will work for all contaminants of concern
- Unsure if this solution would work in all seasons
- Would require pilot testing
- No known species can survive without dilution
- If dilution needed, requires larger footprint than available until the pile is gone
- Long-term solution that may not meet immediate needs

During the session, Don Metzler referred to this alternative as a wetlands system. Assuming that the wetlands would be designed to reduce the concentrations of contaminants, discussions focused on pumping contaminated ground water into this system and the difficulties of finding plant life that could thrive in the high salinity found in the ground water. Subsequently, Mr. Metzler clarified that he sought to use the water infiltrating the subsurface from such a system to accelerate flushing of the ground water contamination to the river. Mr. Metzler believes this system would be desirable to the EPA.

In discussions subsequent to the VE session, Mr. Metzler further clarified that the system he and EPA had in mind did not involve contaminated water, and that the system would only contain water diverted from the river. Moreover, EPA’s interest in this approach stemmed exclusively from the enhanced flushing attained from the infiltration of fresh water. To avoid the impression that this concept of a fresh water system would comprise treatment wetlands, a second option would be a “surface water infiltration system.”

12) B. Diverting 900 gpm of river water and routing it through a surface water infiltration system located between the well system adjacent to the river and the tailings pile.

The surface water infiltration system consists of stream flow segments and a series of ponds located behind check dams. Leakage from the surface water system to underlying ground water accelerated flushing of contaminants toward the river. Near-shore wells prevent the contamination from adversely affecting ecologically sensitive river backwaters. This alternative requires construction of an additional sediment-settling pond to hold river water prior to delivery to the surface water system.

Pros:

- Inexpensive and simple solution
- EPA likes this approach
- Accelerates the removal of ammonia and uranium from shallow ground water
- Fits with ground water remedies that may be applied after the pile is moved

Cons:

- Unsure if near-surface soils will facilitate infiltration of the full 900 gpm
- Would require pilot testing

Both of these alternatives have potential for the longer term and may be incorporated into future land use. The team recommends further investigation for a future solution.

Recommendation:

Combine selected elements from Alternatives 2, 9, and 12.

1) Divert up to 150 gpm from the Colorado River, pass it through filtration and inject the filtered water into a well field located adjacent to the river. The injection area near the river would provide dilution to the backwater channels with the potential for endangered fish habitat. This action constitutes all of Alternative 9A.

2) Divert an additional 900 gpm from the Colorado River and route it through a surface water infiltration system located between the river and the tailings pile. This action constitutes all of Alternative 12B.

3) Place an extraction well field between the toe of the pile and the surface water infiltration system proposed under alternative 2 (to intercept contaminated ground water under and immediately down gradient of the pile) and place this water in a lined evaporation pond. This action is similar to Alternative 9 except that a) the extraction wells are located close to the tailings pile instead of along the river, and b) the evaporation pond would be located north of Moab Wash and directly south of the existing settling pond. The evaporation pond could use enhanced evaporation methods (e.g., TurboMist) that could significantly reduce the pond size.

Actions:

1) Don Vernon will research and resolve the issue of water disposal (e.g., how much disposal can be achieved through effective enhanced evaporation strategies.

2) Cheri Bahrke will contact the State of Utah to determine if the aquifer is a drinking water aquifer. Ken Karp believes this is known from comments received on the Environmental Impact Statement (EIS) and requested the call not be made.

3) Don Vernon will recalculate the size of evaporation pond needed

4) John Ford, Dave Peterson, and Al Laase will determine the amount of water to extract and inject to propose the optimum well configuration.

5) John Ford will integrate this recommendation with the current interim action.

End of current text

Attachment 1

State of Utah
Underground Injection Control Program
Class V
Injection Well Permit Application Package

STATE OF UTAH

UNDERGROUND INJECTION CONTROL PROGRAM

CLASS V
INJECTION WELL

PERMIT APPLICATION PACKAGE

Table of Contents

Contents

PART I

GENERAL INSTRUCTIONS

The Underground Injection Control (UIC) Rules authorize the injection of fluids (UAC R317-7). The following instructions outline the procedures, documents, and information needed for a Class V well permit application.

1. The applicant shall submit an original Permit Application and a Technical Report. Both documents are to be submitted in triplicate to the:

   Utah Department of Environmental Quality
   Division of Water Quality
   288 North 1460 West
   P.O. Box 144870
   Salt Lake City, Utah 84114-4870

   ATTN: Ground Water Protection Section

   Telephone inquiries: (801) 538-6146

2. Signature on Application: The person who signs the application form will often be the applicant; when another person signs on behalf of the applicant, his/her title or relationship to the applicant should be shown in the space provided. In all cases, the person signing the form should be authorized to do so by the applicant. An application submitted by a corporation must be signed by a principal executive officer of at least the level of vice president or his duly authorized representative, if such representative is responsible for the overall operation of the facility from which the activity described in the form originates. In the case of a partnership or a sole proprietorship, the application must be signed by a general partner or the proprietor, respectively. In the case of a municipal, state, federal or other public facility, the application must be signed by either a principal executive officer, ranking elected official or other duly authorized employee. The Division shall require a person signing an application on behalf of an applicant to provide proof of authorization (40 CFR Part 144.32).

3. An application will not be processed until all required information of sufficient detail has been obtained. When an application is severely lacking in detail or the applicant fails to submit additionally requested information in a timely manner, the application may be returned.

9. An application which involves the injection of a fluid containing radioactive materials shall be accompanied by a letter or other instrument in writing from the Utah Division of Radiation Control, stating that either the applicant has a license from the Division of Radiation Control governing the disposal of radioactive materials; or that the applicant does not need a license. In the case of radioactive materials disposal, the Division of Radiation Control must receive a copy of the application for an injection permit. The copy should be mailed to:

   Utah Department of Environmental Quality
   Division of Radiation Control
   168 North 1950 West
   Salt Lake City, Utah 84114-4850

PART II

PROCEDURAL INFORMATION

The staff will review the application for completeness. During the completeness review, the applicant may be contacted for clarification or additional information. When all pertinent information is present, a notice that an application has been received may be given to other state agencies and local governmental entities interested in water quality control and industrial waste management. A draft permit that may include a Statement of Basis will be prepared by the Division and transmitted to the applicant for review. Comments from the applicant may result in changes to the draft permit, after concurrence by the Executive Secretary. After Executive Secretary approval, the draft permit will be subjected to public comment and/or a public hearing. In either case, a notice will be provided to inform the public that a draft permit has been prepared.

Requirements for the public notice include:

1. That a public notice be published for each draft permit, permit amendment, or permit renewal that has been prepared. The notice will appear within each county where the proposed facility or discharge is located and each county affected by the discharge.

2. The Executive Secretary will mail notice of the application to affected persons and certain governmental entities.

A public hearing will be scheduled regarding an application when requested by the Water Quality Board (Board), the Executive Secretary, the applicant, or any affected person within thirty (30) days following newspaper publication.

The Board may act upon a permit application, a draft permit, permit amendment, or renewal of a permit without holding a public hearing when:

1. Adequate public notice and comment period has been provided, including: (a) notice of the application has been mailed to persons possibly affected by the proposed permit; (b) notice has been published at least once in a newspaper, regularly published or circulated within each county where the proposed facility or discharge is located and in each county affected by the discharge; and

2. Within thirty (30) days following publication of the Board's notice the Executive Secretary, the applicant, or an affected person has not requested a public hearing; or

3. An application to amend a permit will result in an improvement of the quality of the fluid authorized to be injected and if the applicant does not seek to increase significantly the quantity of fluid to be injected or to change materially the pattern or place of injection.

After resolution of any public comment the Executive Secretary shall issue or deny the draft permit, permit amendment, or permit renewal. Within thirty (30) days of issuance, a copy of the permit or permit denial will be mailed to the applicant.

PART III

CLASS V INJECTION WELL

Permit Application

1. Type of Permit Application (check one)

   [ ] Initial Application

   [ ] Permit Renewal, Original Permit No. ________________________________

   [ ] Permit Modification, Original Permit No. ____________________________

2. Type of Permit (check one)

   [ ] Individual Well Permit

   [ ] Area Permit

3. Applicant (must be the operator if owner/operator are different):

   ____
   (Individual, Corporation or Other Legal Entity)

   Address: ____
   (Permanent Mailing Address)

   City:____________________________State:______________ Zip:______________________

   Telephone Number: ____

4. Facility owner: ____

   ____
   (Individual, Corporation or Other Legal Entity)

   Address: ____
   (Permanent Mailing Address)

   City:____________________________State:______________ Zip:______________________

   Telephone Number: ____

5. Facility status: Federal_ State_ Private__
Public__ Other (indicate)_______________

6. List those persons or firms authorized to act for the applicant during the processing of the permit application. Include a complete mailing address and telephone number:

7. List all activities presently conducted by this facility which require an environmental permit:

8. List all environmental permits or construction approvals received or applied for relevant to this facility or this location (do not include this permit application):

9. Type of operation(s) producing the proposed injectate (include appropriate SIC Codes):

10. Proposed Injection Operation

Facility name: ____

Facility mailing address: ____

Facility location: ____

Street address: ____

City: ____

County: ________________________________ Lease: ________________________________

No. of Wells* : ______________________________

Township; Range; Section; and 1/4, 1/4 Section: __________________________________

Latitude: _____________________________ Longitude: ___________________________

Survey: ______________________________ Abstract: ____________________________

* Location(s) of injection well(s) should be identified on all maps, including those maps required by the Technical Report.

11. Are the proposed injection well(s) located on Indian land? _______Yes/No

12. Proposed Injection Program:

    a. Source(s) and type(s) of injection fluid(s):

    b. Type(s) of injection well(s) (borehole, drainfield, gravel filled pit, etc.):

    c. Elevation of drill collar:

    d. Total depth(s) of well(s) measured from the drill collar:

    e. Depth(s) of screened interval(s) measured from the drill collar:

f. Wellhead locations: <u>Well I.D</u>. <u>Surface or Subsurface</u>?

g. Geologic name(s) of formation(s), member(s), or submember(s) of the lithologic unit(s) in which injection will occur. Include depth(s) from surface.

h. Proposed Annual Injection Volume (Acre-Feet):

Well ID: ________________ Average: ________________ Maximum: ______________

i. Proposed Injection Rate (Gallons Per Minute):

Well ID: ________________ Average: ________________ Maximum: ______________

j. Proposed Injection Pressure (PSI):

Well ID: ________________ Average: ________________ Maximum: ______________

13. An application map or maps, depicting:

a. The approximate boundaries of the tract of land on which the injection well activity is or will be conducted.

b. The location of the injection well(s) as related to facility boundaries and to adjacent survey lines.

c. The general character of the areas adjacent to the place or places of injection such as residential, commercial, recreational, agricultural, undeveloped, etc.

d. The boundaries and ownership of tracts of land adjacent to the facility boundaries. Include, with the map a list containing the names and mailing addresses of the owners of the tracts of land adjacent to the facility boundaries keyed to the map.

14. Name(s) and address(es) of surface owner(s) [attach additional sheets if necessary]:

15. On an attached sheet(s), list the names and mailing addresses of persons or parties that may be effected by the injection operation; e.g. adjacent property owners, mineral lease owners, water right owners, nearby municipalities and other governmental bodies or installations.

16. The names and mailing addresses of persons identified as affected parties, were obtained from:

    (Source: City, County, School or Water District Records or Abstract Co.)

17. Provide a separate list of owners of mineral interests in the tract of land on which the well will be drilled and include a complete mailing address for each. Include other mineral interests that could be affected by contaminant movement over the life of the project.

18. Submit the Technical Report with Application.

19. Certification of submitted information.

____ , ______________________

(Name of Company Official) (Title)

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Signature: ________________________________ Date: ________________________

SUBSCRIBED AND SWORN to before me this _____ day of _____________, 20____.

My commission expires on the ____day of _______________, 20____.

____

Notary Public in and for

(SEAL) ___________________________________ County, Utah

PART IV

TECHNICAL REPORT OUTLINE
FOR CLASS V
INJECTION WELL APPLICATIONS

Applicants should consult with Division staff prior to initiating a UIC Permit application for injection operations to review the information necessary for a Technical Report.

A Technical Report, prepared under the direction of a professional engineer or geologist, containing as a minimum the following information must be submitted as an attachment to the application. Adjustments in these requirements may be made by the technical staff upon a showing of good cause that the situation so warrants.

Items required for inclusion in the technical or engineering report are:

1. A map indicating the location {with name(s) or number(s)} of the proposed injection well(s) and all producing wells (oil, gas, geothermal, etc.), exploratory boreholes, injection wells, monitoring wells, abandoned wells, dry holes, surface bodies of water, springs, mines (surface and subsurface), quarries and water wells (drilled or dug) within the area of review. The area of review is defined as the area within a two (2) mile radius of the injection well (or project perimeter, for area permits), or a radius calculated per 40 CFR 146.6(a). Include any other artificial penetrations not noted. The map must show pertinent surface features including residences and roads. Faults (known or suspected) must be indicated. Only information of public record is required to be included on this map.

   Include a tabulation of well I.D.'s and types, well depth(s), water level(s), owner(s), chemical/physical analyses (if available) and other pertinent data keyed to the map. All water wells must be identified as to their use (i.e., public or private drinking water, livestock watering, irrigation, etc.).

2. On a map of appropriate scale, indicate the location of the public water supply well that is nearest the proposed injection well in an hydraulically down-gradient direction. Attach pertinent data on the well {see (1) above}.

3. A piezometric map of all ground water in the area (confined and unconfined) using information from wells near the proposed injection well(s). This map must also show the vertical and lateral limits of underground sources of drinking water (USDW's), i.e., total dissolved solids (TDS) are less than 10,000 milligrams/liter. Include the position of these sources relative to the injection formation, direction(s) of ground water flow and an estimate of average linear velocity for each ground water system present.

4. For those wells or boreholes, etc. noted in (1) above which penetrate the proposed injection zone, provide the following additional information:

   a. A tabulation of: operator; lessor; well I.D.; well type and construction data; date drilled; distance from proposed injection well(s). In addition to this information, copies of available casing and cementing records shall be submitted including the appropriate State forms and cementing affidavits. Tabulation shall be keyed to map in (1) above.

b. A cross-section schematic of the well or borehole. See attached form.

5. Proposed corrective action plan for all wells, boreholes, etc. within the area of review which penetrate the injection zone but are not properly completed or plugged.

6. Description of local topography and geology pertinent to the injection operation. This information shall include but is not limited to:

a. A USGS topographic map (1:24,000 scale, if available), or other map if the topographic map is unavailable, extending two miles beyond the property boundary; depicting the proposed injection well(s), the property boundaries, the facility and its intake and discharge structures; any hazardous waste treatment, storage and disposal facilities; existing injection well(s); and wells, springs, surface water bodies and drinking water wells listed in public records or otherwise known.

b. Surface geologic map and cross-sections on a scale necessary to depict the local and regional geology of the area. Indicate the location of the injection well(s) on the geologic map.

c. Two cross-sections perpendicular to each other crossing at the proposed injection location. These cross-sections will include, at a minimum, all available log control, geologic units structure and lithology that occur between the surface and the lower confining bed below the injection zone. If a major structure exists below the injection zone, the sections will be projected to as deep as necessary to show the structure. All aquifers and their water quality must be identified, including the base of 3,000 mg/L and 10,000 mg/L TDS water. This cross-section will be to the necessary scale to detail the local geology at least within the area of review, and preferably for the area surrounding the injection operation.

d. Parameters of upper and lower confining strata (lithology, permeability, etc.) for all USDW's present and the injection zone.

e. Description of faulting and fracturing or lineations in the area (vertical stereo aerial photos with lineation interpretations are suggested). Pay special attention to faults and fractures that intersect USDW confining zones.

f. Depositional, structural and tectonic (seismic) history of the area including lithology and hydrologic properties of all units penetrated by the proposed well.

g. Structural contour map on top of the proposed injection zone.

h. Isopach map of the injection zone. (Between major confining zones.)

1) Isopach of permeable zone within injection zone.

2) If more than one zone is being requested, isopachs of each permeable zone.

7. Geohydrology - reservoir mechanics of injection interval (give sources of information):

a. Porosity, hydraulic conductivity, transmissivity and temperature.

b. Natural reservoir pressure (bottom-hole pressure) or hydrostatic head; fluid saturation, chemical and physical characteristics of formation, and formation fluids.

c. Location, extent, and effects of known or suspected faulting, fracturing and/or formation solution channels.

d. Proposed formation testing program to obtain an analysis of the chemical, physical, and radiological characteristics of the receiving formation. This information will be used to determine the compatibility of the formation with the proposed injectate.

e. Fracture gradient or formation breakdown pressure of injection zone and all confining beds.

8. Characteristics of injectate:

a. A detailed description of the chemical, physical, radiological and biological characteristics of the fluids to be injected. Complete chemical analyses of all inorganic constituents should be reported in part per million (ppm) or mg/L. If organic fractions are present, all such constituents should be reported in ppm or mg/L, as individual percentages by weight, or in other appropriate terms. Give analysis of each individual fluid stream and its percentage of total injection volume. Data on the toxicity and degradability rates and levels are required on final composite injection stream.

b. Corrosion test on all facilities that will be in contact with the injection stream, including any long string casing.

c. The anticipated average and maximum rate of injection in gallons per minute and gallons per month. Estimate the yearly volume of injected fluid and the anticipated life of the project (show calculations).

9. Detailed outline of construction and completion of the proposed injection wells (all new materials required unless otherwise approved by the Executive Secretary):

a. Total well depth from wellhead and wellhead elevation.

b. Type of completion: perforation, open hole, screen, etc.

c. Type, size, weight, grade and setting depth of all casing strings (API standards). Indicate compatibility of casing material with proposed injectate.

d. Proposed cementing procedures and type of cements, including volumes, additives, slurry weight, etc. (Sufficient cement shall be used to circulate to the surface plus a minimum of 20% excess.) Submit service company recommendations along with studies to determine the suitability of the selected cements.

e. Cementing technique and equipment: guide shoe, float collar, plugs, baskets, DV tools, etc.

f. Proposed injection interval(s) and perforating or screen setting depths. This should include the interval(s) to be utilized initially and the entire zone required for future development.

g. Number and location of centralizers, wall scratchers, etc.

h. Size and type of tubing and proposed setting depth.

i. Size and type of tubing packer and proposed setting depth.

j. Diagrammatic sketches of well, wellhead facilities, and any annulus monitoring system.

k. Proposed well stimulation program, acidizing, hydraulic fracturing, etc.

l. Description of proposed injectivity tests (i.e., permeability, reservoir limits, reservoir types, etc.)

m. Proposed open hole and cased hole logging, bottom-hole testing, coring, etc. Minimum logging requirements will be set by technical staff.

10. Wellhead installations:

a. Description of pressure and volume monitoring systems for injection and annulus systems.

b. Description of filters including type, capacity and capability.

c. Description of injection pumps including type and capacity.

d. A schematic of the surface and subsurface construction details of the system (showing location of all flow lines and pre-injection system).

e. Detailed description of any pre-injection treatment process, including a flow diagram with each injection stream identified along with tank capacity and construction materials.

f. Plans for disposal of liquid, solid or semi-solid waste from the pre-injection treatment system.

g. Detailed plans and specifications of all wellhead-associated facilities.

1) The wellhead-associated facilities should be diked to totally contain spillage and control run-on and run-off.

2) The areas (including loading, unloading, tanks, pumps, and filters) within the wellhead dike should be lined with an impervious material or reinforced concrete and drained to a sump, then routed to fluid holding facilities or returned to the process circuit.

3) All fluid preinjection holding facilities should be aboveground tankage with adequate design strength and constructed of a material compatible with the injection fluid.

4) Process fluids or emergency storage facilities should be aboveground vessels or artificially lined ponds with adequate design strength and constructed of a compatible material. If lined ponds are used, they shall have a leak detection system installed.

5) Ponds used for emergency storage during well maintenance or workover will not be used for any other purpose.

11. Other subsurface operations in the area:

a. Discussion of other injection or mining operations in the area, including names, distance from the proposed well, and the injection interval or mining interval.

b. Hydrologic implications of proposed well as related to the existing operations.

12. Injection well operation:

a. Expected maximum and average injection pressures.

b. Calculated changes in reservoir pressures, formation fluid displacement, and direction(s) of dispersion of injected fluids.

c. Describe provisions for continuous activities necessary for proper well maintenance and operation, and qualifications of personnel who will operate and supervise the injection well and related facilities.

d. Contingency plan and description of facilities to cope with well failures or shut-in (Emergency Response Plan).

Note: A mechanical integrity testing plan and schedule may be required for certain types of Class V injection wells on a case-by-case basis.

13. Representative background ground water analyses for the receiving aquifer and all USDW's in the area of review shall be provided from locations adjacent to and hydraulically downgradient and upgradient from the proposed injection well(s). The analyses shall include all parameters listed in the state Drinking Water Standards and Ground Water Quality Standards, and any additional parameter(s) of concern reasonably expected to be present in the injectate.

14. Plans (including maps) for meeting the following monitoring requirements:

    a. Monitoring wells shall be completed into the injection zone and into any USDW above or below the injection zone. Properly completed existing water wells may be utilized in meeting this requirement.*

       Monitoring wells shall be completed in such locations hydraulically down-gradient from the injection well(s) as to detect the migration of injectate contaminants, injectate reaction products or formation fluids towards points of withdrawal or natural seepage (springs) of ground water.*

    b. Monitoring of ground water shall include, at a minimum, all State Drinking Water Standards, all State Ground Water Quality Standards and any additional parameters reasonably expected to be present in the injectate. Baseline analyses for these parameters shall be completed at all monitoring wells noted in (a) and submitted to the Division of Water Quality prior to injection well start-up. Indicate the proposed monitoring frequency.*

    c. Indicate the proposed parameters of injectate monitoring, to include at a minimum those noted in (b) above as well as injection pressure, volume and flow rate. Indicate the proposed frequency of injectate monitoring.

* NOTE: Ground water monitoring may not be required in all cases.

15. Proposed Well Plugging Abandonment Plan in the event of well failure or upon expiration of the project.

16. A certificate indicating that the applicant has assured, through a performance bond or other appropriate means, the resources necessary to close, plug, and abandon the wells. Include all calculations and results of all calculations used in determining the financial resources required.

ARTIFICIAL PENETRATION REVIEW

Well (etc.) I.D. ____

Control: ______________________________ Status: ______________________________

Operator: _____________________________ State Forms: _________________________

Lease: ___________________ Distance from Injection Well:________________________

Plugging Details

Well Diagram

POTENTIAL PROBLEM(S):